FEBRUARY 1960

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ILLUMINATING ENGINEERING

Journal of the
ILLUMINATING ENGINEERING SOCIETY

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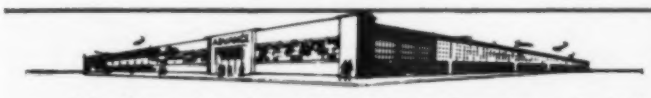

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Keystone's Engineered Lighting Division recently announced a new series of fluorescent fixtures specially designed for schools, offices, stores, institutions and public buildings. Featured in this 4-foot and 8-foot series is the Achromatic, a 2 or 3 lamp quality luminaire which has become the industry's leader in a few short weeks.

Since 1898, footcandle levels have doubled every 10 years. Due to a more scientific evaluation of required lighting levels, the new series developed by Keystone has resulted in luminaires that provide *Optimum Visual Value and 'see-ability.' The series offers a brand new concept in controlled refraction of light. This concept provides uniformity of brightness without harsh shadow reflection. Maximum illumination is delivered at peak efficiencies. In addition to the Achromatic, other fluorescent fixtures in the new series include the Wafer, Prismalite and Envoy. Rapid start and slimline models are available for a number of versatile mounting arrangements. For additional information, send for Bulletin #F 859.

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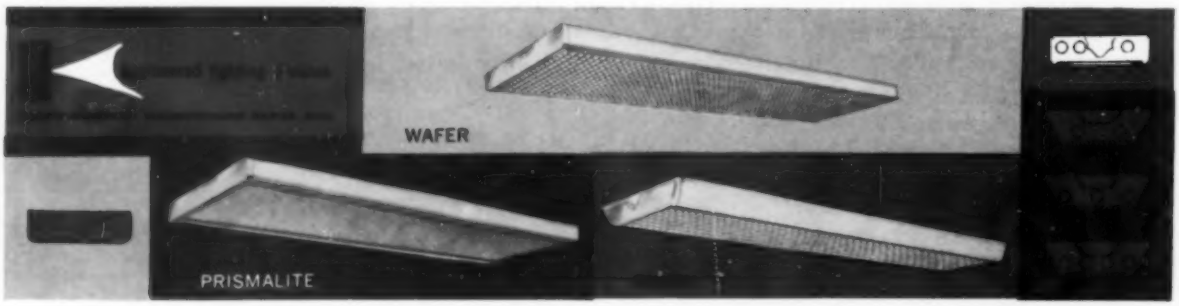

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How architectural design and planned lighting create an image of strength and friendliness in a bank

Somewhere between the coldness of Greek temple design and the casualness of the ranch house prototype, there should be an architectural concept for banks that inspires confidence, reflects stability, yet is not formidable. So reasoned Harry Weese, architect. Out of that came the new home of State Bank of Clearing, Chicago. Meaningfully shaped and purposefully illuminated, an image is created at State Bank which speaks of progressiveness, strength and friendliness.

Lighting is planned to create an inviting effect and at the same time is highly functional. Patrons move through an entrance of restful subdued light into a lower lobby of slightly higher light intensity, then into the main, high ceiling banking area. There a combination of indirect light and spot lighting presents a dramatic effect. A suspended ceiling achieves a peripheral clerestory so walls of brick are texture-lighted day and night.

On one side of the main high room is the officer area and on the other, the teller area—both flooded with functional, non-glare, high intensity light which tends to direct customers to the areas. Curtis-AllBrite visioneers worked hand in hand with architect, illuminating engineer and contractor to accomplish this illumination innovation. Curtis-AllBrite Lighting, Inc., AllBrite Lighting Division, 352 Shaw Road, So. San Francisco, California; Curtis Lighting Division, 6135 West 65th Street, Chicago 38, Illinois.

CURTIS
visioneers in planned lighting
All-Brite

Banking is serious business, so high visual acuity is necessary in the areas where close work is done. Here the officer area is bathed in a high level of soft, shadowless, glare-free illumination that is accomplished by a Curtis Strato-Lux Luminous Ceiling. Exclusive Curticell Louver-Diffuser panels combine diffusion of light source with proper shielding of the diffusing medium.

State Bank of Clearing, Chicago, Illinois, where an architectural concept and planned lighting bring something new and different in bank design and function. Illumination, both day and night, heightens an atmosphere of friendliness.

The main banking area where walls are texture-lighted by a wash of indirect lighting achieved with Curtistrip. Spotlights in the suspended ceiling add an atmosphere of action and provide high function, too.

Architect: Harry Weese & Associates.

Electrical Engineer: Sam R. Lewis.

Electrical Contractor: Crescent Engineering.

Yes, Bowling Alleys Too Can Get Striking Lighting with Standard Fixtures . . . by LITECONTROL

In these pages over the years we have been pleased to show you lighting installations in banks, offices, Supermarkets, specialty stores, schools and gymnasiums, churches, libraries and industrial plants. All of these installations have one thing in common — the superb quality of the lighting is obtained with *moderate in cost, standard fixtures* — right out of our catalog.

The same circumstances prevail with this ultra-modern bowling alley. It is an impressive establishment — with sixty continually busy alleys, a modern restaurant and snack bar and air-conditioning. Litecontrol fixtures were chosen to illuminate this handsome interior and to blend into this very well designed structure. They were used throughout except for the area immediately over the alleys.

Whether *your* next installation is a bowling alley or a bank, you can get results on a sensible budget with LITECONTROL.

INSTALLATION:
Thruway Lanes, Buffalo, N. Y.

AREA: Bowling Alley

ARCHITECT: Milton Milstein

ENGINEER: Walter H. Sherry & Associates

DISTRIBUTOR:
Buffalo Incandescent Light Co., Inc., Buffalo, N. Y.

ELECTRICAL CONTRACTOR:
Frey Electric Construction Co.

FIXTURES:
Litecontrol No. 6042TS 4-lamp approx. 2′ x 2′ recessed fixtures; No. 3324RS and 3428 2-lamp recessed fixtures. 2-lamp, 8-ft. strip fixtures over alleys by others.

FIXTURE SPACING: 11 feet on centers

INTENSITY:
Average 45 foot-candles after 6 months operation (alley area not included)

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Museum Lighting

FEATURED on the following 13 pages are the lighting designs for two well-known art collections.

One—the Solomon R. Guggenheim collection of modern masters, and non-objective art. The museum housing this collection is the extraordinary building in New York City, designed by Frank Lloyd Wright—his last work. So unorthodox is this architecture that it cannot even be described as "modern." Even among modern designs, this is in a class by itself.

The other—the Abby Aldrich Rockefeller Folk Art Collection. This is a collection of nineteenth-century American folk art, displayed in a ten-gallery museum building adjacent to the Williamsburg (Virginia) Restoration. The building housing it was designed by the Department of Architecture of Colonial Williamsburg and every aspect of its design reflects the environment of the nineteenth-century people who created its art objects.

No two buildings could be more different in character. No two art collections could differ more widely in their expression. For the lighting design of each, however, the problems were identical. Design approach for both lighting installations had to consider (and solve) the problems of:

- Color rendition of the art.
- Vertical illumination of sufficient quantity and pleasing quality.
- Reliance on reflected light from the walls for general and background illumination.

There were, of course, differences. One sought to blend with daylight; the other to block it out. One dealt with open, sloping galleries; the other with nineteenth-century rooms. Their common denominator, however, is the ever-interesting factor of their lighting design.

George Cserna

1

MUSEUM LIGHTING

ALMOST universal interest has been stirred in the new Guggenheim Museum on New York City's Fifth Avenue. It is Frank Lloyd Wright's last work, his only building in New York City, and is considered by knowledgeable critics to be his masterpiece, a summing up of his life's work. Every aspect of its controversial design has been described in the architectural press; indeed, the popular magazine and news fields also have considered this unusual building a "top story."

It would be redundant to outline in great detail the structure of this extraordinary building. To orient its lighting design, however, it is necessary to note its basic spiralling form (**2** and **3**), the astonishing vastness of its interior spaces (**1**)—and its function as a museum for a modern art collection. In fact, its every departure from conventional patterns is part of its "lighting story," especially lighting for paintings and sculpture.

Wright's plan for lighting the paintings (if he considered the paintings at all, which some critics doubt) centered primarily on daylighting—from his graceful and spectacular domed skylight (**1**), and from the skylight "slots" formed by the spiralling structure of each level. He apparently visualized their display against a bisque-colored background, recessed in effect as on an easel, back onto the outward sloping walls. The viewer stands on the inclined spiral ramp; the wall slopes away from him, admittedly a difficult circumstance for viewing paintings. The Museum's curator, James Johnson Sweeney, revised some of these adversities in a most ingenious manner, and greatly to the benefit of the art display. His views required complete revision of the lighting system, which I worked out with him as described below.

Instead of paintings recessed into what would amount to an inaccessible sloping "niche," Mr. Sweeney mounted the unframed paintings on an almost invisible four-foot steel arm (**4**), (**5**). The entire background, floor, walls and ceiling, was painted high-reflectance matte white, and a light-

Solomon R. Guggenheim Museum

By ALFRED A. BINDER

2

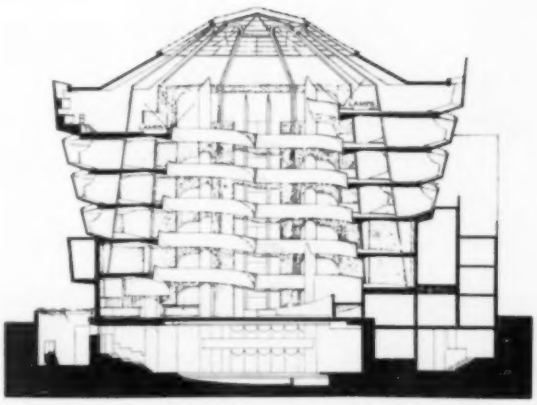
George Cserna

. . . . for contemporary art, displayed in a building of unconventional design

ing system was designed to create a strong back light balanced by an even stronger front light. The resulting effect is of a painting "floating" in lighted space—an illusion curiously harmonious with the nature of the modern art. This scheme for mounting brings the paintings approximately flush with the viewers' ramp, permitting art lovers to study modern masters closely, or at a distance.

Lighting Details

Frank Lloyd Wright's basic concept, I believe, was to simulate outdoor art exhibits. His vast center glass dome and spiralling skylights bring in natural illumination in a manner and direction not usual to interiors. My own basic concept, in designing for electric illumination, was to retain this effect of natural light on the paintings. Extensive tests were conducted to reach a color rendition which would achieve this effect in relation to these particular paintings. Fluorescent lamps in groupings of three, with a lumen proportion of three



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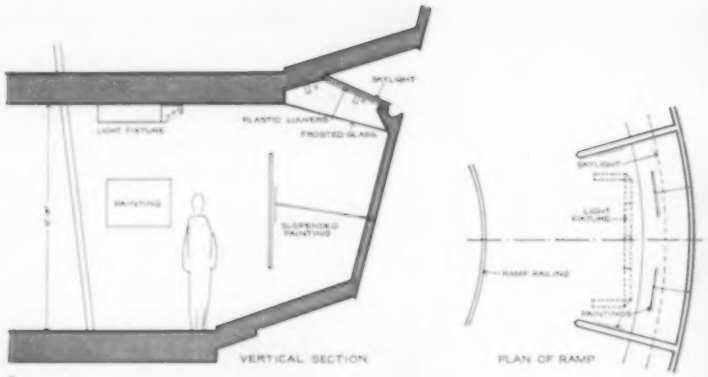
AUTHOR: Chief, Illuminating Engineering Dept., American Lighting Corp., Hackensack, N. J. Mr. Binder designed the lighting and equipment for this museum, coordinating with the curator, James Johnson Sweeney.



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5

George Cserna

times cool white to one warm white, seemed the most successful answer in the opinions of Mr. Sweeney and myself. Our judgment on this color choice for portraying the artists' true colors has met the approval of numerous artists and critics.

For the lighting design, I started on the fourth level of the museum. A brief description of this level will outline our problems. As are other display levels, it is composed of a ramp rising from the center hall on a three-degree grade (**6**). It is circular and divided into seven sections by eight-inch concrete structural walls extending approximately ten feet from the exterior wall. Each section is approximately 25 feet wide by 27 feet deep to the circular parapet of the ramp. Because of the structural needs of the building, the floor near the peripheral walls on the third, fourth and fifth levels rises at an approximate 30-degree angle. This rise is protected by a curb four feet from the wall. As already mentioned, the paintings are hung four feet from the outside wall on one-inch square steel armatures, and on each of the dividing walls.

Luminaire

To deliver illumination of suitable color, quantity and direction on the vertical face of the paintings (of varying sizes), a special luminaire had to be developed (**7**). Naturally, the ideal would have been to incorporate these lighting needs into the building design, right from the start. Such, however, was not the case. The plan to suspend some of the art in mid-air and display it closer to the viewer (and out of range of the skylight slots) was, as already discussed, a revision of original plans. Even the circuiting of the finished building did not take into account an electrical lighting system of this nature, and in the end was one of the factors influencing luminaire design.

Other factors: the light was to be focused on the pictures, some of which were mounted on armatures, some hung conventionally on the dividing wall. Avoidance of distraction by hot spots was important (achieved so that wall was evenly illuminated from floor to ceiling with accent on pictures).

An adjustable reflector with four planes was developed, with an approximate focal point of 30 inches from the two inner planes, to be swiveled over a 48-inch area when mounted four feet from the wall at about a nine-foot height. The upper and lower planes washed the balance of the wall at every adjusting angle, floor to ceiling. Light spillage to the floor and ceiling was controlled by cut-off points on the luminaire. Each unit was fused to avoid circuit interruption if a ballast failed. Each four-foot lamp section developed 8800 lumens.

For uniform light distribution and to flatter the semicircle of each gallery, these units were mounted in groups of six to eight in the form of a "C" with the open end to the spectator. They were made in 38-inch and 50-inch sections, custom-fitted with inner sleeves, no overlapping joints and butted perfectly. Sixty-degree and 90-degree corners were made to complete each set and ends were welded without overlap for a completely smooth surface. To increase efficiency and permit easy installation, the entire group is one open wireway and trough, but there are no light leaks. To prevent glare and permit even diffusion a prismatized acrylic diffuser was used.

Skylighted Galleries

Each of the third, fourth and fifth ramps have skylight slots over each gallery. These skylights are composed of frosted panels of glass on the

interior; and interior triangular space of approximately 12 inches at one end, 24 inches at the other and a panel of glass on the exterior. The purpose of these skylight slots is to supply daylight to each gallery.

On the exterior of this extraordinary building the skylights are tucked into the ascending spiraling divisions formed between ramps. These divisions break up the circular concrete pattern of the structure during the day. In addition, the divisions allow for a gradual enlargement of the building toward the top and give a sense of balance to the structure.

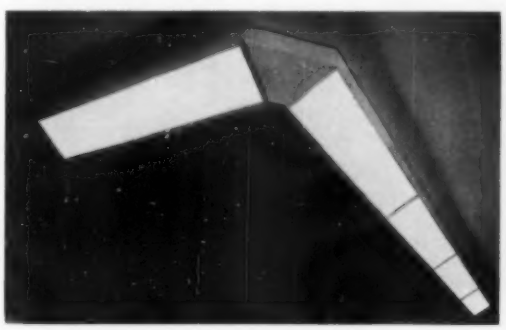
Within the gallery as originally conceived, the sunlight through the dual skylights created uneven shadows and gloom. Also since there was no supplementary illumination on the ramps, the contrast with the illumination on the pictures was uncomfortable. The colors of the pictures against the original café-au-lait of the walls was not pleasing. To correct this, as mentioned previously, the floor above the curb in back of the pictures and the surrounding walls and ceiling over the display area were painted matte white. Against the exterior skylight 45-degree plastic louvers with half-inch cubes were inserted to deflect the rays of the sun. In order to avoid the emptiness in back of projecting pictures, eliminate all shadows of the armature and picture, get a comfortable ratio of illumination on the ramps and carry out the daylight theme of the exterior architecture at night, I decided to balance the back light on the pictures with the front light. By calculation, I found two continuous rows of TD17 lamps would accomplish this. Due to a lack of power, I had to settle for one row of TD17 and one row of high-output lamps. The lamps were side mounted at selected positions so that the light of each row eliminated the housing shadow of the other. Sun coming through the skylights merged with the artificial light in perfect harmony. The astute observer may note a slight imbalance in these skylights because of the difference of the 2:1 lumen output of the lamps.

The final result is, of course, that the pictures seem to float in a wall of light. The illumination on the paintings and background is about 150-200 footcandles (170 fc on the face of most paintings). Illumination on the background and on the pictures is approximately equal despite the light being focused on the picture. Obviously the pigments on the paintings absorbed light and the background reflected light, resulting in an almost equal balance. Light on the ramps is in about a 4:1 ratio to this. There are no shadows, neither from the armature nor the suspended paintings; visual comfort is quite satisfactory.

6 *George Cserna*

Enclosed Galleries

On the first and second ramps (**8**), where there are no skylights, the ramps are divided into galleries of approximately the same width as the upper levels. The walls are circular, each gallery wall forming an arc. An imaginary line was drawn 48 inches from the center of this arc and the luminaires (designated as G.G.#1) were mounted perpendicular to this line in groups of five and six but giving the appearance of one large luminaire of 20 feet or more. By adjusting the reflectors of each 48-inch unit, the entire radius of each wall was uniformly illuminated with the accent on the pictures. The walls were painted white and despite the concentration of light on the pictures the foot-



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Ezra Stoller

candle readings for wall and background are 125-150 footcandles. This combination of luminaire and reflective walls produced approximately 40 footcandles on these ramps, well within comfort range.

On the first level, just above the lobby, additional 4-inch by 6-inch, 40-watt recessed lighting units were placed for supplemental illumination and slight accent. These units are diffused by quarter-inch tempered acid-etched glass for very low brightness.

9

George Cserna

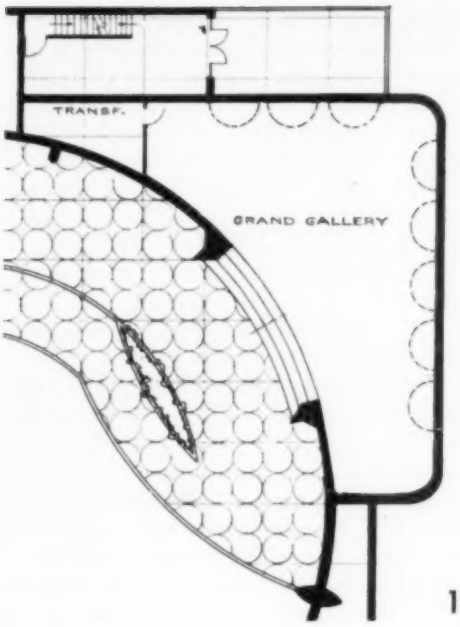
Grand Gallery

The next task was illuminating the Grand Gallery (**9** and **10**). The Grand Gallery is 52 feet long, 24 feet deep opposite the entrance, 38 feet wide on one side, 15 feet wide on the other side and 24 feet high (see diagrams). This room can also be viewed from a balcony on the second level. Statuary and pictures up to 13 feet high are shown in this room. There are half-moon shaped skylights, eight feet long, in the flat ceiling.

In addition to focusing on the paintings there was a problem here of lighting the statuary evenly by reflected light. Direct illumination or central illumination was impractical as the sculpture varied in size and position. Such lighting would also detract from the pictures. Silhouetting was prohibited on esthetic grounds. In general, it was desired to equal in the Grand Gallery the quality and quantity of illumination achieved in the ramp galleries.

Calculations showed that the G.G.#1 units at 13 feet 6 inches above the floor would deliver approximately 90-100 footcandles. Reflected illumination for the balance of the room would be approximately 30 footcandles. To minimize contrasts within the room, uplight was necessary to merge with light from the skylights and retain the light characteristics of the room (**11** and **12**).

To show the statues under approximately 100 footcandles, which seemed optimum to me, 250-300



10

11 George Cserna

footcandles were necessary in the area of the pictures. A luminaire with two TD17 lamps and one high-output lamp produced 37,500 lumens per eight-foot section and could deliver all of my requirements. However, the D sound rating of the ballasts would have sounded like a brass band. Fortunately, to the left of the Grand Gallery there is a room behind a soundproof fire door with eight-inch concrete walls. By remotely installing all the ballasts in this room, a noiseless installation was achieved. Research in wire sizes for this 100-foot remote installation showed that #8 and #10 wire had to be used from the ballasts to the fixtures with no more than two or three fixtures on a common feed, varying with the distance.

A luminaire was then developed to perform the following:

(1) Illuminate the 13-foot 6-inch wall uniformly with no bright spots.

(2) Retain the lamp color proportions as in the ramp galleries.

(3) Provide uplight to merge with the light from skylights and give an even, subdued illumination to the ceiling.

(4) Provide low brightness for visual comfort while not causing distraction from the pictures.

With only three weeks to opening date, such a luminaire could only be developed on the drawing board. There wasn't enough time for a mock-up or actual test. The first step was the design of a reflector with three planes. A different plane was placed in back of each of the two TD17 lamps, the upper lamp to illuminate the lower wall, the lower

12

lamp for the upper half of the wall to the height of the luminaire. These lamps are cool white. The center high-output lamp is warm white and the reflective plane is designed to blend the color to the entire wall.

For ventilation and the necessary uplight, a three-inch opening was designed the full length of the luminaire over a section of the upper TD17 lamp. This section as well as the diffuser is shielded by a grey louver with a 45-degree cutoff in half-inch-square cubes. The use of this diffuser under

this powerful source achieved the low brightness desired.

The luminaire is 20 inches wide, approximately five inches high and in 72-inch and 96-inch lengths. Two raceways were built into each section. One in front for the home run wiring, the other for feeding the individual fixture from the front raceway. (For a cross section of the luminaire see sketch.) The front top of the luminaire is mounted parallel to the ceiling on 11-foot 6-inch by ⅝-inch O.D. pipe and the front is 48 inches from the wall. The bottom of the luminaire is at a 14-degree angle to the wall. Ten of these luminaires were joined to form a large U, with one short leg. The beginning of the row at the ballast source is connected through the eight-inch wall by an exact sleeve section, two corners were built to conform and correct the row around the room, the short leg of the row was connected through another sleeve anchored to the wall and plastered in. The result is a solid built-in appearing section conforming to the contour of the room. Pictures and statues may be viewed equally well from the floor level or from the balcony. There is no performance loss because of the remote installation.

Lobby

The last problem before the opening date was illuminating the lobby. During daylight, the lobby is lighted by the large skylight dome, 100 feet in diameter, approximately 125 feet above the lobby. The interior of this dome is composed of an eight-sided skylight of frosted glass. The exterior, several feet above, is a similar skylight. To retain the fine appearance of the dome all supplemental illumination for dusk and night had to be indirect. This is from three complete rows of fixtures with remote ballasts located on the sixth level, 30 feet below the dome. Each fixture contains one 96-inch TD17 de luxe lamp developed only a few weeks before the opening of the Museum. The first two rows are composed of a modified parabolic reflector with one side nine inches high, the other four inches high bolted together on the short sides. The dual pattern was plotted to aim at the opposite side of the dome at the center of one of the eight sides of the skylight. This angle projected to the opposite corner of the lobby. The third row was another modified parabola with each leg eight inches high and the lamp mounted against one side. This reflector has two hinges 48 inches on center and two slides that allow up to 180 degrees swivel. Thus, positioning is readily possible to provide maximum light in the lobby. These units produce approximately 30 footcandles of illumination in the lobby after dark, against an average of 50 footcandles under ideal daylight.

The brilliantly illuminated pictures are a thrilling spectacle as they can be seen in complete detail and color at every point across the ramps. Contrast ratios are maintained wherever possible of less than six to one. The lobby itself is a glorious stage. The illuminated spiral ramps, back-lit by the galleries, gently climb to the dome that seems bathed in perpetual sunlight.

Acknowledgements

Work on the Guggenheim installation was challenging but most rewarding. The staff and craftsmen of American Lighting Corp. carried out every detail of design despite the pressures of almost intolerable deadline. The staff of the Daylight Electrical Construction Corp. headed by A. Alper installed the equipment on a "right the first time" basis. The lamp department of General Electric Co. provided speedy service and reliable information. To James Johnson Sweeney, the director of the Guggenheim Museum, goes the highest praise. He had to make the tough decisions on design acceptance, many of them different from the original specifications, but he had a sure esthetic judgment and the courage to follow it.

Abby Aldrich Rockefeller

Folk Art Collection

By LAURENCE S. HARRISON

Plate I. Doorway and Entrance Gallery.

MUSEUM LIGHTING . . . .

preserving the historic nature of the architecture and art collection . . .

When our country won its independence, one of the most fascinating evidences of its creative spirit arose in the many artifacts, paintings, sculptures and decorative expressions which flowered in the homes and communities of the new nation. The late Mrs. Abby Aldrich Rockefeller sustained her deep interest in American folk art by collecting over many years of her lifetime the most outstanding examples available. This Collection has been housed in Williamsburg, Virginia within a new, ten-gallery museum building adjacent to the Williamsburg Restoration.

The building was designed by the Department of Architecture of Colonial Williamsburg in consultation with Mrs. Nina Fletcher Little, a leading authority on nineteenth century folk art, and the author. Its character is unusual because while the rooms are functionally well-adapted to exhibition purposes, they are designed to maintain an early nineteenth-century atmosphere. In dimensions, in trim and finishes they reflect the environments of the people who created the objects shown.

This primarily involved the adoption of a lighting quality biased toward the spectral values of tallow candles and whale oil lamps. The lighting problem also required that the anachronism of modern lighting fixtures be hidden as far as possible. This prohibition of course included air con-

AUTHOR: Consulting Engineer, Scarsdale, N. Y., formerly of the Metropolitan Museum of Art, New York, N. Y.

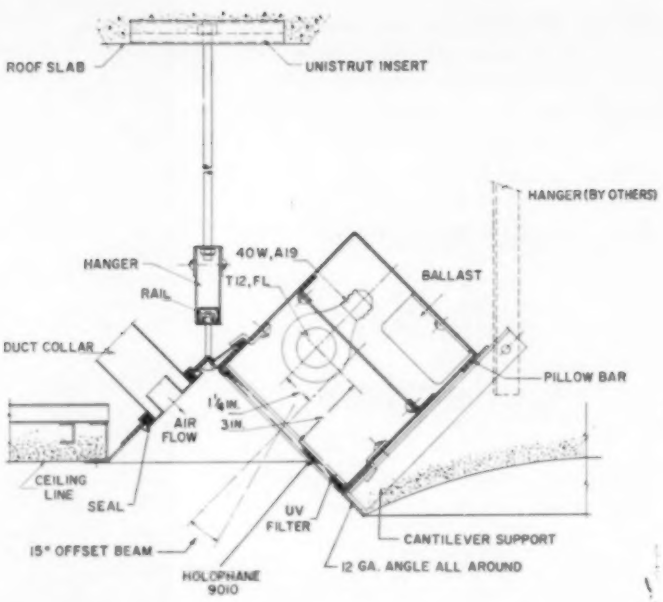


Figure 1 (right). Cross section of lighting trough for seven rooms.

Plate II (below). Typical gallery.

ditioning equipment. The galleries have a nine-foot ceiling height on the first floor, and an eight and one-half-foot height on the second so that no surface in any of the rooms may be said to be entirely hidden from view at all times. Moreover, the common occurrence in ordinary nineteenth-century American houses of rarely painted, white plaster walls posed serious questions of brightness contrasts.

Design Approach

The following basic points of approach to a satisfactory design were decided upon after a thorough study of the Collection and many discussions of proposed exhibit installation ideas were considered:

- A light quality, of 2700 to 2800K, having satisfactory color rendering properties;
- A maintained, vertical illumination on the walls of from 18 to 25 fc;
- Reliance on reflected light from the walls for general illumination in eight of the ten rooms with special treatments in three of the ten;
- Integration of supply and return air elements with lighting means;
- Flexible provision for concealed spot lamps;
- The use of filters, opaque to ultraviolet radiation, to avoid such photo-chemical hazards as might be present in view of the higher suscepti-

bility to damage of many Collection items;
- The blocking out of all daylight to avoid window glare and the higher radiation hazards inherent in natural light.

The Entrance Gallery on the first floor, the second floor corridor, an early nineteenth-century kitchen interior and a period room from a house in Scotland County, North Carolina, on the second floor required special attention.

General Gallery Treatment

Plates I and II, and Fig. 1, show the solution employed for seven galleries on both floors. Linear air diffusers and return air slots were incorporated into a continuous, inverted, ceiling trough with removeable, combination fluorescent and incandescent, box-type luminaires. No metal cross strips or glazing muntins nor separators interrupt an unbroken opening around the entire trough facing the walls. The ceiling line is also unbroken.

Being continuous, the problem of mitering at the corners of the room was difficult, particularly at the corner fireplaces. This difficulty was accurately solved by preassembling all mitered sections at the factory before installation. The continuous line of lamps was made to conform to the various room dimensions, without discernible shadow gaps, by employment of various wattages of T12, fluorescent lamps, either rapid- or trigger-start and warm white, deluxe quality, plus occasional 40-watt, A19, standard inside frost incandescent units.

While such an arrangement does not provide a uniform light output per linear foot, variations of illumination along the wall are hardly noticeable except to a light meter. On the contrary, the changes soften the appearance of the white walls and actually strengthen the viewing of detail when paintings with darker backgrounds and subdued contrasts are hung in the higher level areas.

The line of lamps is on a longitudinal axis which is offset 1¼ inches from the focal center of Holophane No. 9010 lenses, mounted end-to-end, mitered and ground at the corners. This results in a 15-degree asymmetric beam providing the recommended 60-degree angle of incidence along a sight line five feet, six inches from the floor.

In the back of the lenses, six-inch wide panels, generally four feet long, of one-eighth-inch thick, Rohn & Haas, IIUF, acrylic, ultraviolet filter are placed end-to-end. This material is transparent to practically all wavelengths in the visible spectrum with a very sharp cut-off below 400 millimicrons.

At all windows and door openings the clear ultraviolet filter panels are replaced by white Plexiglas panels of about 30 per cent light transmittance to avoid interference with window effects and, more importantly, to suppress glare in the eyes of visitors entering the room.

Plate III. Detail of lighting trough showing linear air diffusers.

Window cavities were unavoidably very shallow for artificial lighting. Plywood backs were painted a light gray tinted with green as foliage overtones would appear in a light mist outside. Antique glass was used in the lower sash having appreciable obscureness but enough transparency to show false brick work on each side of the embrasures. The upper sash used Kingsport Luminex with Satinol finish. This obscure glass presents soft, fleecy, irregular configurations to the cool-white, fluorescent lamps concealed behind the window frames on each side and at the top. The cool white color suggests daylight behind the upper sash in contrast to the room illumination.

One problem emerged later on in that at night the windows, having been blocked to daylight, permitted no artificial light to show through the louver blinds behind the permanent weather sash on the outside. This resulted in a "dead" appearance of the building to passers-by. Accordingly, the original plywood backs of the false window cavities on the street side were removed and two layers of one-quarter-inch Plexiglas, having a total over-all light transmittance of less than 10 per cent, were installed. The inner layers were sand blasted on one side to increase diffusion within the cavity, and the outer layers have normal polished surfaces. The

Plate IV (left). Nineteenth-century kitchen interior.

Plate V (below). Detail of lighting units between summer beams.

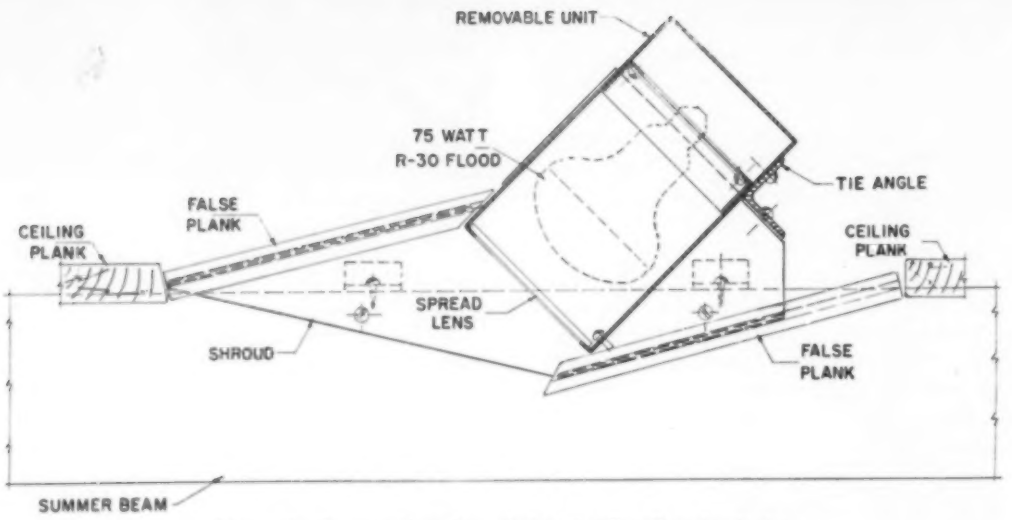


Figure 2. Cross section through "kitchen" gallery luminaire.

result does not appreciably affect the performance of the false window lighting but does present through the blinds a soft, home-like glow to passers-by in the street.

Special Gallery Treatment

The Entrance Gallery also employs the inverted trough scheme for wall lighting but the center of the room, having over ten feet of ceiling height, is illuminated by conventional cove lighting with two lines of rapid-start, 40-watt lamps on a variable reactance dimmer. Plate III shows a concealed 75-watt, R30, floodlamp and a spread lens lighting a carved eagle, from the stern of a sailing ship, over the Main Entrance to the Museum and a glimpse of the Entrance Gallery itself.

Plates IV and V and Fig. 2, show the method used for wall lighting in Gallery No. 7, which has the early nineteenth-century kitchen interior on the second floor. Here, a wood-plank ceiling laid over summer beams, 21 inches on centers, prevented the use of a continuous trough with fluorescent light as in other galleries. The solution accepted was to provide the appearance of "slightly lifting one floor plank and lowering the adjacent one to form a slot permitting light from the attic to shine through."

In this case individual, removeable luminaires are mounted between metal shrouds which are aligned and tied together within the ceiling cavity by a continuous structural angle and attached to the wooden summer beams. The lighting units and shrouds are finished inside and out with matte black and each unit contains sockets for a maxi-

Plate VI (right). Carolina Room.

Plate VII (above). Luminous paneled ceiling, Carolina Room.

mum of three 75-watt, R30 reflector floodlamps. These three sockets permit limited flexibility. The socket in the center may be left unused or equipped with an R30 spot or flood. The two sockets at the ends of the unit (not shown in Fig. 2), are angled at 15 degrees toward the center so that their light beams cross. With a panel of Corning Crystalite, prismatic, spread lens, these two angled lamps provide an exceptionally wide and even spread along the wall without excessive spill-over of light on the adjacent wooden beam edges. The availability of the new, 30-watt, R20 floodlamp increases the range

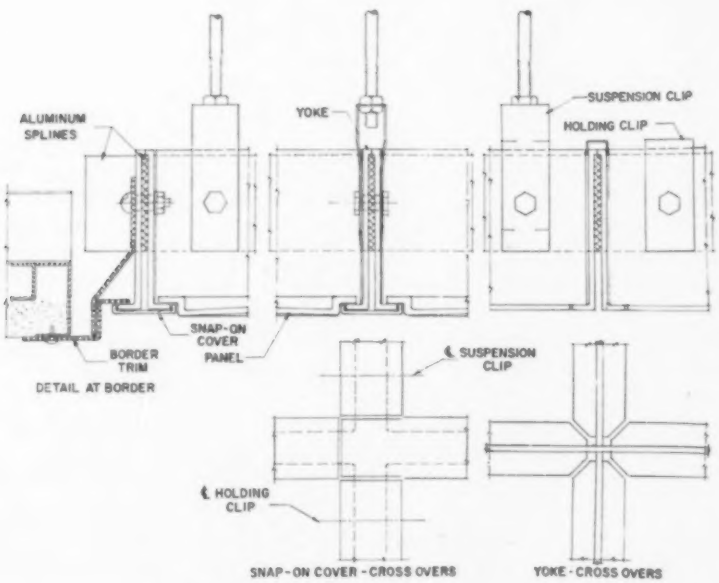


Figure 3. Detail of translucent suspension grid, Carolina Room.

Plate VIII. Main staircase, accenting Ship's Figurehead.

of flexibility for this luminaire. At the end of each row, adjacent to the doorways, a panel of Hexcel, Honeylite louvering, painted matte black, is also inserted to cut the spread of light off from visitors entering the room.

Plates VI and VII and Fig. 3, show the method used to provide a luminous ceiling in the Carolina Room. Due to objections to patterns of modern commercial luminous ceilings for this room, the suggestion was made to design a plastic ceiling to resemble a velarium stretched across the ceiling cavity as closely as possible. This, of course, meant that the supporting grid would be translucent, which has, of course, been tried many times.

To provide translucent plastic suspension without light leaks poses many questions due to the appreciable amount of thermal expansion in long, narrow strips of acrylic or other plastic having the rigidity and tensile strength enough for this purpose. Moreover, any aluminum used for reinforcement would have a different coefficient of expansion while working with the plastic.

The ceiling panels are formed into rectangles approximately 39 x 41 inches with narrow flanges at the edges and a shallow camber arching the spans between to prevent any sag. When the ceiling is lighted these cambers are not noticeable. Fig. 3 shows how the supporting elements were designed.

Yokes, each consisting of two halves of extruded Plexiglas, clipped to a supporting grid of one-eighth-inch thick and two-inch wide aluminum bars mortised together and suspended from the roof slab. The yokes provide the necessary flanges, as on tee-bar supports, for carrying the panel edges, and the assembly is held firmly together and hidden by snap-on strips of extruded Plexiglas.

Light passes under the aluminum grid and the light transmittance of both yokes and cover strips assembled in place total little more than that of the ceiling panels alone. When assembled properly no light leaks are possible, under the existing conditions, and both aluminum and plastic members are free to move, within their calculated expansion and contraction limits, by the use of metal spacers for all holding and supporting clips. Panels are removeable from below for relamping and cleaning by lifting and turning.

Cavity lighting employs eighteen, 40-watt, rapid start lamps in six rows, dimmer controlled. The room level is kept at about 15 fc for display, but may be raised to 40 fc for inspection, cleaning or maintenance of the room and contents.

One special effect, as shown on Plate VIII should be described. In the main stairwell, between the first and second floors, a carved wooden, ship's figurehead of an Indian maiden is mounted. The problem here was to provide dramatic accent from above by casting a single, sharp shadow of the figure to one side. However, the image, when thus projected, resulted in obscuring the underside of the figurehead subduing the sculpture itself by the boldness of its own shadow.

Concealed accent lighting was provided behind small apertures in the vertical faces of the dropped ceilings on the second and first floors, consisting of Century, 400-watt, #1653, Optical spotlights, permitting accent both downwards and upwards upon the sculpture. The additional beam from below regardless of shutter adjustments cast interfering shadows, spoiling the dramatic effect desired. These were avoided by carving an accurate image mask in an aluminum plate, inserted at the gate of the optical system in place of the rectangular shutters normally supplied. This shaped mask confines the light beam from below within the outlines of the sculpture.

Viewing this dramatic figurehead either from above or below, the visitor can appreciate the manner in which "Minnehaha," having proudly served her world-roving missions on the prow of an American clipper ship, now equal pride, bears testimony to a creative and dynamic period in our history which this remarkable Collection and its fine building demonstrate.

lighting for

Sports and Recreation

"Tasks" involved for fun activities were hardly among those measured for the Blackwell researches. Good lighting has its benefits there, nevertheless, and good designs in recreational areas win prizes. The six installations shown on these pages all placed high in local MMILJ competitions last spring.

• Bowling Alleys

Marked increase in the popularity of bowling over the past decade has given a new dimension to bowling alley proprietorship. No longer is it sufficient to "have an alley." Competition is in terms of "extras"—attractive surroundings, bars, restaurants, game machines.

Higher lighting levels than are necessary for the visual task of bowling are another manifestation of the attempt to attract customers. The *IES Lighting Handbook*, Third Edition, recommends 30 footcandles, vertical, for recreational bowling. In the two alleys shown here, lighting levels well exceed this recommendation.

The owners of Allied Bowling Lanes, Buffalo, N. Y. (photo below), entering a new business, in a new building, knew little about modern construction and lighting techniques, but they did know what effect they wanted—a distinctive, modern illumination system with a high lighting level.

Solution proposed was a combination of saw-tooth ceiling over the alleys and luminous ceiling panels in the score desk area and over the refreshment counter and lounge.

The 32 alleys are lighted by four continuous rows of bare two-lamp 96T12 fluorescent strips, concealed by a saw-tooth ceiling. Pin lighting is by a 48T12 lamp mounted two feet above the alley and 12 inches in front of the number 1 pin. Measured footcandle level after six weeks of operation showed 42 footcandles, vertical, on number 1 pin.

Over the approaches to the alleys, four 48T12 430 ma fluorescent lamps, in surface-mounted eight-

Light surfaces and matte finishes used throughout the quarters of Allied Bowling Lanes, Buffalo, N. Y., are an important contribution to the comfort of the lighting installation. Luminous panels over the refreshment counter produce a level of 60 footcandles.

Highland Bowling Lanes in Toledo has 70 footcandles on the alleys from five rows of two-lamp 96-inch fluorescent strips concealed behind a sawtooth ceiling. Recessed downlights in ball return area provide low-level illumination for identification of balls and do not interfere with reading of telescore screens.

Refreshment area at Highland Lanes is lighted by a three-sided cove. Perforated metal downlights over bar and recessed incandescent units over food booths are for highlighting.

foot luminaires with diffusing plastic panels are installed one to each pair of alleys. Measured lighting level in this area is 42 footcandles.

Luminous panels, 6 by 16 feet, installed on approximately 22-foot centers and equipped with continuous rows of T12 430 ma fluorescent lamps are used over the score desks. Two- by two-foot plastic panels with 42 per cent noise reduction coefficient supply diffusion and acoustic benefits.

Refreshment bar and lounge in the rear of the bowling alley is lighted to a 60-footcandle level, also with luminous panels. Here, an eight-foot wide panel, with five continuous rows of fluorescent lamps mounted above, extends the entire length of the room. Diffusion and acoustic treatment is with the two- by two-foot plastic pans described above.

Highland Bowling Lanes in Toledo, Ohio, is also a brand new business venture. The owners only request to the lighting engineer was to install something "different," to distinguish Highland from the other bowling alleys in the area.

Alley lighting specified, in line with this request, was five rows of two-lamp 96-inch strips, installed behind a saw-tooth ceiling, providing 70 footcandles. In the bowlers' section, where lighting had to be low enough to permit players to read the telescore screens, 150-watt recessed downlights, installed over the ball return area, provide sufficient light for bowlers to identify their numbered balls.

Restaurant area behind the alleys is lighted by an attractive three-sided cove, with two rows of single-lamp fluorescent channels used side by side. The rows are arranged so that the lamps in one row overlap the end of the other row, washing out shadows. Two 2000-watt dimmers permit adjustable lighting levels. Additional illumination for highlights over the food booths is obtained from recessed incandescent units.

Owners of both alleys were well-pleased with the results of the lighting installations and, apparently, illuminating engineers were impressed, too. Robert Finucane, Frey Electric, Buffalo, N. Y. won second prize in the Western New York Section's MMILJ contest for the design of lighting for Allied Bowling Lanes; Clifford Crookes, Toledo Edison Co., designer of the illumination system for Highland Bowling Lanes, took second prize in the Northwest Ohio Section's MMILJ competition.

• Ski Lodge

"Boot and board folk," rugged on the ski slopes, look to the luxury of comfortable lounges after dark. Rustic atmosphere with modern conveniences is the objective and tasteful decor combined with good lighting fulfill this goal at the Ostego Ski Club in Hidden Valley, Mich.

Ostego Ski Club began modestly in 1939 as a warming hut equipped with one oil heater and one tow rope on a ski slope. Paralleling the increasing nationwide enthusiasm for skiing has been the growth of Ostego. Today, it is operated year-round (offering golfing in the summer), has a 12-unit electrically-heated motel, a dormitory and several rustic lodges.

It was the lighting plan for the cocktail lounge in the Main Lodge that puzzled the electrical contractor on the job, and the design and engineering aid supplied by C. F. Kramsvogel, Consumers Power Co., Traverse City, Mich., resulted in a first prize "My Most Interesting Lighting Job" in the Western Michigan Section's 1959 contest.

The cocktail lounge in the Main Lodge, a 49-by 57-foot room, is, functionally, four separate areas—bar, lounge, card room and dance floor and dining area. Visual division of the four areas, with an over-all unity of design was the objective, and the lighting provided the "invisible" means for creating this effect.

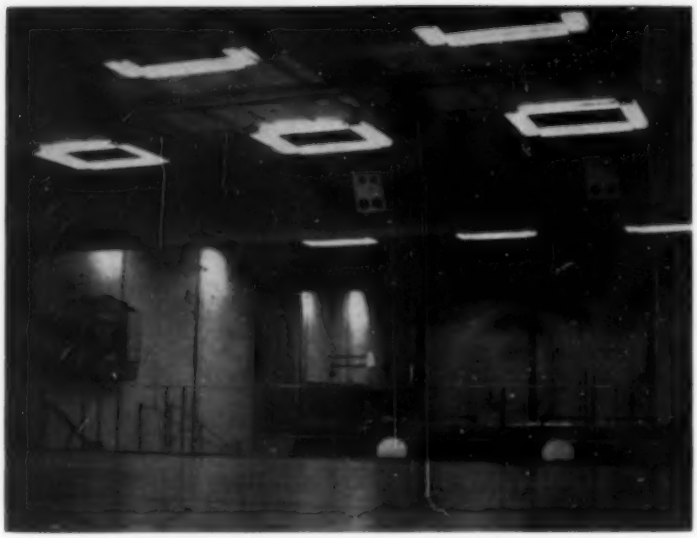
Basic lighting objectives called for a well-balanced, visually comfortable atmosphere, with variable lighting levels. Much emphasis was placed on lighting as an integral part of the decorative plan and the fixtures were carefully selected to blend with the decor.

General lighting system used over the dance floor area and lounge are 36-inch recessed dome units with 300-watt lamps. Result is a warm wide-spread diffuse illumination from the domes, and pleasant sparkle coming through the rows of perforations in the metal fixture baffles. The center of the room, decoratively delineated by a wood floor of nine-inch square blocks of Parka Oak and outlined by the carpet which covers the rest of the room, is used as a dance floor and dining area and banquet room. For additional highlighting at banquets and dances, recessed incandescent spots have been added to the genera lighting plan.

In the lounge area, furnished with comfortable sofas and chairs, portable lamps are used against the background of overhead illumination. White incandescent lamps, shades with light linings and open tops, proper placement of the portables in relation to the visual tasks, are important contributions to comfort.

In the card room area, a combination of 300-watt R20 recessed units and 24-inch indirect fixtures give functional illumination with minimum glare. Switching arrangement here permits perimeter or central lighting to fill the area or—a combination of both. Weathered barn siding, planed to a beautiful finish is the wall panelling for the card room section of the lounge and behind the bar. Incandescent lamps in the card playing area and recessed incandescent downlights over the bar display the natural tones of the wood.

Highest illumination level in the cocktail lounge does not exceed five times the lowest level. Good brightness ratios in the various areas between task and field of view add to the comfort. Adjustable auto-transformers, selected for their insensitivity to load, high efficiency and low cost, control the lighting levels in each area, producing a range of atmospheres for the pleasure of skiers returning from the slopes.



Proviso West High School gymnasium, Hillside, Ill., an area 240 by 102 feet, houses four separate gym areas, divided by electrically-operated folding partitions. Lighting system with extra-high-output lamps is one of the first instances of the application of this source to a high school gym.

• High School Gym and Pool

The Polaroid amateur snapshot does not do justice to the lighting of this school gym (Proviso West High School, Hillside, Ill.). Actually, it is one of the first areas of this nature to use extra-high-output lamps. In the gymnasium, there are 124 luminaires, symmetrically arranged and integrated with the 28 sky domes (five by seven feet), mounted 45 feet above the main gym floor, 30 feet above the upper floors. These are each lamped with F96TD17 lamps. Footcandle readings in the center floor were 65 footcandles, tapering off to 45-50 footcandles along the edges of the basketball court. The luminaires are relamped via hydraulic platform on a group replacement plan.

For the swimming pool at Proviso West, the usual problems of maintenance and humidity were overcome with the use of weatherproof, stainless steel luminaires, each containing three fluorescent lamps, shielded with opaque glass lens and operated on 277 volts.

Mounting is 32 feet above the pool; maintenance is from a network of catwalks above the ceiling. The final layout provides 25 footcandles. To enhance the appearance of the pool, twenty-four 500-watt square units are installed at intervals, underwater.

Architects for the area were Perkins & Will, Chicago; lighting engineer was Robert Kaspar, Elmhurst, Ill., whose honorable mention entry this was in the Chicago Section's 1959 MMILJ contest.

Weatherproof luminaires, with three fluorescent lamps, for resistance to humidity and temperature conditions, were chosen for swimming pool lighting at Proviso West. Catwalks above 32-foot ceiling provide for relamping.

• Ice Skating Rink

Designing the lighting system for a new building, where it is not necessary to modify an optimum design to fit various existing conditions—wiring, sockets, etc., enables the lighting engineer to plan a system that *is* best for the area. Such was the situation at Playland Ice Skating Club, a large semi-public skating rink in the metropolitan Detroit area. Both owner and architect, once convinced of the value of good lighting, were eager for an installation that would be, not only serviceable, but compliment the design elements, as well.

Main skating rink (200 feet by 86 feet) is housed in a curved roof building of wooden arch construction, measuring 38 feet from the ice to the highest point on the ceiling. The roof ties into the walls on a circular arch, about eight feet six inches above the floor. Structural members of the curved roof divide the ceiling in a diamond pattern, with the diamonds stained a variety of yellows, browns and orange. Walls are light blue, with 50 per cent reflectance; ice surface has a reflection factor of 75 per cent.

Analysis of economic factors, kw load (wiring is 480/277-volt Y-connected secondary) and color rendition qualities resulted in the choice of fluorescent as the light source. Particular fluorescent employed is the 1500-ma lamp, which gives the highest level of illumination from the fewest number of fixtures.

Fixture selected was a modified version of a standard two-lamp fluorescent luminaire, with 45-degree crosswise and 27-degree lengthwise shielding and 30 per cent upward component. Modification by the fixture manufacturer to accommodate the specifications of the job involved the installation of sockets to fit any type of 1500-ma lamp, thereby giving the owner of the skating rink a choice of a variety of lamps.

Lighting layout consists of eight rows of 11 two-lamp fixtures. The six inner rows, directly above the ice surface, spaced on 15-foot centers in the width and 20-foot centers lengthwise, are mounted 22 feet above the ice. Two outer rows, mounted above the grandstand, 14 feet from the floor, use 430-ma lamps, as the proximity of the stands to the curve of the ceiling makes only half the lighting intensity necessary here.

Fixtures are mounted on slotted suspension channel with rod supports to hold the system together structurally. This orients fixtures lengthwise, keeps them rigid and in line. The slotted suspension channel is also used as the raceway, fed by typical conduit drops to the top of the channel.

The one-section ballast selected for use in this installation serves two purposes—eliminates maintenance of a multiple unit and provides the desired weight distribution in the fixture (ballasts are installed in the center of each fixture).

Technical success of the installation can be measured with a footcandle meter. Illumination level on the railing between rows in the grandstand is exactly the same as under a row of fixtures on the ice—30 footcandles at full lighting intensity. Brightness reading off a typical wall is five fL. The 45- by 27-degree shielding results in uniform light distribution, with no shadows or sharp contrasts to interfere with the spectators' view of hockey games or skating exhibitions.

Esthetic success of the lighting system (especially gratifying to the architect and owner) is particularly evident on the multi-colored, diamond-patterned ceiling, where the 30 per cent upward component of the luminaires plays on the colored ceiling pattern, adding warmth and interest to the ceiling design.

Alternate switching provides a 15-footcandle level for skating to a background of organ music, 30 footcandles for hockey games. Relamping is planned on a group replacement schedule at four-year intervals.

Haskell Greenfield, Greenfield & Kronik, Engineers, Detroit and B. F. Segall, House-O-Lite Corp., cooperated in the design of this installation which won third prize in the Michigan Section's 1959 MMILJ competition. Seymour J. Levine was the architect for the rink building; electrical contractors were Miller Bros., both of Detroit.

• Night Club

At the Sultan Club, a subterranean Mecca for relaxing Memphis citizens, "visual task," or first eye-catcher is the bar, an interesting mural made more beautiful by imaginative lighting. The mural depicts a Sultan on a magic carpet gathering twinkling evening stars. Star lights are miniature twinkle lamps embedded in the centers of the stars painted on the mural. The entire mural is additionally lighted to a pleasant glow with continuous 36-inch T6 17-watt fluorescent lamps in a showcase type reflector. Top portions of the lamps have been blacked out to reduce harsh splashes of light near the top and bottom of the mural.

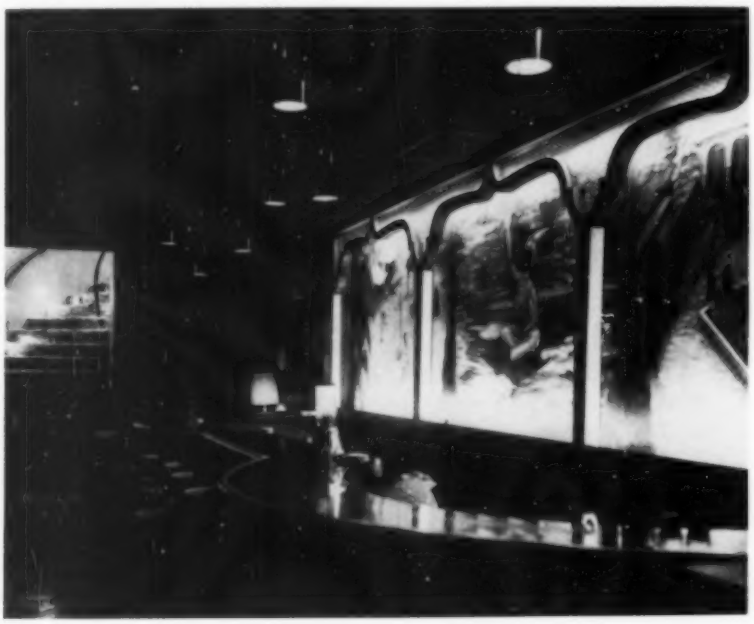
Throughout the rest of the club, the lighting technique is similar, that is, interesting highlighting for conversation pieces, subdued, inconspicuous light for relaxation. Over the bar, almost invisible black cylindrical fixtures contain small seven-watt clear lamps, mounted at varying heights over the bar, at staggered intervals. The low illumination level provided does not make a "splash," but makes the rectangular pieces of colored glass on the bar-top glow with an enticing brilliance.

Other areas of the Sultan Club (not pictured here) include the Harem Room which features low-level lighting from 25-watt recessed downlights and a highlighted planter. Conversation piece in this room are two of the Sultan's handmaidens, behind a transparent veil, showered with light from recessed adjustable fixtures. The customary R30 75-watt lamps, used in such fixtures, have been replaced here with 60-watt inside frost lamps for comfortable brightness levels. Over the Sultans' table, another important decorative element of the Harem Room, is a custom-built chandelier housing a 60-watt lamp.

In the dining room and dance floor area, red and white carpets, draperies and furnishings present a gay scene under the general lighting of recessed downlights containing 25-watt lamps. The bandstand is highlighted by two pull-out recessed R40 colored spotlights, and directly over the solo performer is a recessed drum unit housing two 100-watt inside frost lamps. Large white metal spheres, each containing a cylinder of frosted glass and a 25-watt lamp are installed in four locations in the dining room, adding decorative interest. Step-type dimmers control changes in mood.

Private dining booths, located along the east wall of the club, are separated from one another by transparent draperies. Intimate dining atmosphere here is emphasized by lighting from basket-type woven bamboo fixtures with 25-watt lamps. Step-type dimmers are used here, too, for varying the dining atmosphere.

This job won first prize for D. C. Hooper, lighting engineer, Memphis Light, Gas and Water Division, in the 1959 My Most Interesting Lighting Job competition sponsored by the Mid-South Chapter of IES.



INSTALLATION AT REEDMAN DODGE, INC., ROUTE 1, LANGHORNE, PA.

Lighting an Automobile Display

LIGHTING OBJECTIVE: To provide general display lighting for nighttime attraction and for the merchandising of automobiles.

GENERAL INFORMATION: This automobile display, located in a secondary business district, is basically a large show window for featuring one car at a time. The area is approximately 25 feet by 29 feet. The luminous ceiling is mounted at 10 feet 6 inches, 1 foot 6 inches below the unfinished ceiling. The back wall is walnut panelling (16% RF). Floor is light gray asphalt tile (35% RF).

INSTALLATION: Sixteen rows of fluorescent lamp channel consisting of one catalog No. LA2X196 (two 8-foot lamps in tandem using one 2-lamp ballast) and one No. LA196 (one 8-foot lamp using one 1-lamp ballast) arranged end to end are surface mounted approximately 18 inches above a No. 236 Circular Pattern 3- x 3-foot vacuum-formed vinyl panel ceiling, manufactured by Luminous Ceiling, Inc. The rows are on 18-inch centers and are each equipped with three 96-inch, T-12, 430 ma, cool white slimline lamps. Corrugated vinyl borders are installed on the two sides and the rear of the ceiling to fill in between the formed vinyl panel ceiling and the walls.

Brightnesses after 200 hours' use were: ceiling at 45 degrees, 190 fL; back wall, 20 fL; and floor, 40 fL.

Lighting designed by Arthur V. Schafer, Philadelphia Electric Co., Philadelphia, Pa.
Electrical contractor, Gerhart Keller, Penndel, Pa.

Lighting data submitted by Arthur V. Schafer and George T. Anderson, Jr., Philadelphia Electric Co., Philadelphia, Pa., as an illustration of good lighting practice and to aid in the design of similar installations.

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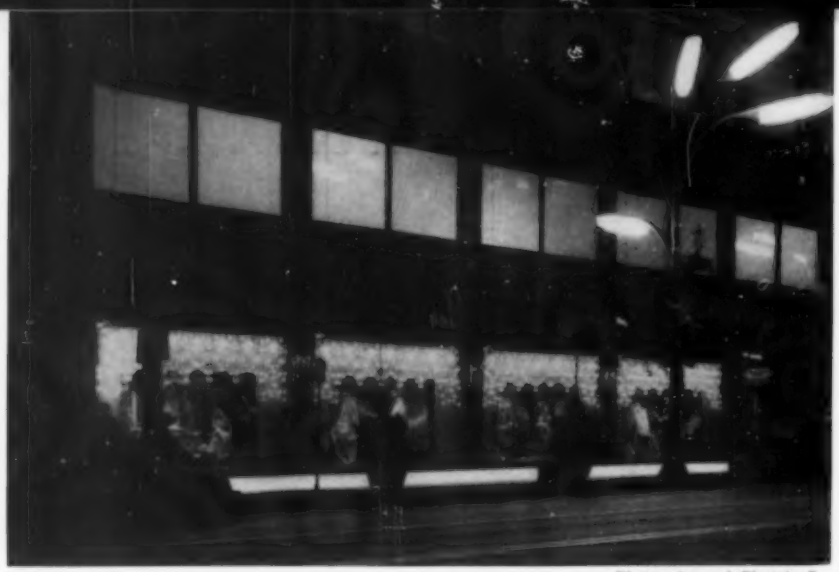

Photo: General Electric Co.

Lighted-Heated Sidewalks

a new dimension in mid-winter comfort for shoppers, theatre-standees, passers-by

IF ANYTHING could draw customers to a store or theatre more surely than a pool of light shining through the night, it would be the promise of a cozy area of warmth, especially in Chicago or New York City from November through March.

At Carson Pirie Scott Co., in Chicago (photo above) an installation of quartz infrared lamps above the display windows is designed to take the wintry chill off the window shoppers. In addition, the quartz lamps provide 500 footcandles of light on the sidewalk. System was carefully designed to complement the architecture of the store.

For the theatres (below) light is from incandescent units recessed in the marquee; heat from an installation of reflecting fixtures each with one or more long thin tubular heating elements.

Lunt-Fontanne Theatre, New York ▶

▼ Helen Hayes Theatre, New York

Photos: Consolidated Edison Co. of New York

A Constant-Wattage Ballast For Two or More Mercury Lamps

By V. W. OLSON

THERE ARE many applications in lighting where two or more lamps are lighted on the same pole or support. One such application is on the centerway of a boulevard or expressway where one pole supports two arms, one with a lamp over one lane of traffic and the other over the lane of traffic travelling in the opposite direction. Another application is in parking lots and gas stations where one pole or support sets on a small island and may provide for two or even four luminaires.

But why a single ballast to light two or more lamps? A two-lamp ballast usually can be made smaller in size and more economically in cost than the two single-lamp ballasts. Besides the initial savings in size, weight, and production cost, the contractor is also saved installation costs. He has only one input or primary circuit to install, and uses less space. These savings both to the manufacturer and the user point up the necessity for two-lamp ballasts. Time, together with the manufacturer's ingenuity, will determine the requirements of and/or the necessity for three, four or more lamps on a single ballast. Incidentally, as a small indication of a trend, a four-lamp ballast has already been manufactured and sold.

Now why should this ballast be constant-wattage? The same arguments hold for a two-lamp ballast as for a single-lamp ballast. Admittedly, reactors for certain voltages are less expensive and smaller; but reactors cannot be employed for all voltages. The voltages which are not suitable for use with a simple reactor require the use of autotransformers in conjunction with a reactor, a high-reactance autotransformer or some other means to change the source voltage to a voltage suitable for proper operation of the lamps.

In this paper, all ballasts other than constant-wattage shall be referred to as conventional ballasts when mentioned as a group and the exact type of ballast given only when two types are compared.

All conventional ballasts have one similarity in that they require the source voltage to be kept quite close to the rated voltage of the ballast. Most manufacurers of conventional ballasts have agreed that ± 5 per cent variation from rated voltage is acceptable, but even this variation results in a variation in the watts to the lamp of from $\pm 6\frac{1}{2}$ per cent to ± 11 per cent. This is a total variation in watts to the lamp, between maximum and minimum, of from 13 per cent to 22 per cent depending upon the type of conventional ballast used. See Fig. 4.

Now compare the performance of a constant-wattage ballast with the conventional ballast; for a line voltage variation of ± 13 per cent, or a total variation of 26 per cent, the wattage to the lamp is normally held to ± 2 per cent or to a total variation of 4 per cent. For this total of 4 per cent change in wattage, the contractor has no taps to select. In most applications he does not have to worry about the voltage drop from one end of a long run to another. All lamps will burn with the same brilliance within the tolerance of lamp or ballast manufacturing. See Fig. 5.

The advantages of multiple operation rather than series operation of two or more lamps from one ballast are self-evident. Now, how can a single constant-wattage ballast be made to operate two or more lamps and maintain independent operation of each lamp? The schematic drawing in Fig. 1 shows the circuitry used in the development of a two-lamp ballast. The circuitry shown in Fig. 2 could also be used, but is less favorable for purposes of isolation. The ballast can be made to operate three lamps by adding another condenser and lamp, as shown by the dotted line. Additional lamps can be added in the same manner, but it must be remembered that when speaking of 400-watt mercury lamps, the ballast must be large enough to handle approximately 450 watts for each lamp the ballast is intended to carry. A 900-watt ballast

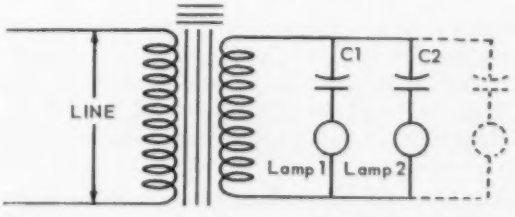

Figure 1. Circuit diagram for two-lamp constant-wattage ballast, isolated, high-reactance type.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHOR: Jefferson Electric Co., Bellwood, Ill.

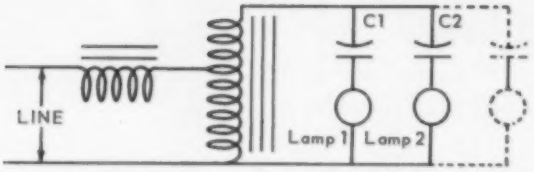

Figure 2. Circuit diagram for two-lamp constant-wattage ballast, non-isolated, reactor type.

would be required for two lamps, a 4.5 kilowatt ballast would be required to operate ten lamps.

Operating Characteristics of a Multi-Lamp Ballast with Circuitry of Fig. 1

The ballast, itself, was of the high-reactance type, having an isolated 115-volt 60-cycle primary and a secondary. The secondary was loosely coupled to primary by shunts placed between the primary and secondary. The ratio of the secondary to primary turns was approximately 2:1. The ballast was set up on two standard lamps, each lamp having an arc voltage of 135 volts. The condensers were adjusted so that each lamp was operating at 410 watts to 412 watts with each lamp in a vertical position. Complete tests were then made. The power factor of the line was unity. The crest factor was under 1.7. The regulation was found to be excellent, well within the 2 per cent mentioned earlier. In fact, the regulation actually was better than 1 per cent. A production item made to this circuitry should manifest the same characteristics, but for reasons beyond the scope of this paper, constant-wattage regulation shall be considered as ±2 per cent. The first hurdle had been passed. The ballast did operate two lamps and had acceptable characteristics for constant wattage. See Fig. 6.

The question now arose as to what would happen under abnormal conditions of operation. If one lamp is extinguished will the other lamp keep burning? Would it damage the other lamp? Would the other lamp be in a condition of stable operation?

With the ballast set up for normal operation of two standard lamps, lamp number one was extinguished by opening the lead to the lamp. Lamp number two remained lit. There was a slight reduction in lumen output as the watts delivered to lamp number two reduced by about 10 per cent. The regulation of the lamp watts remained within ±2 per cent and the power factor of the line remained high. It had dropped from unity to 98 per cent.

The test was repeated except that, after extinguishing lamp number one, it was immediately reconnected in the circuit. This was to check on hot restrike. After a normal time lapse, lamp number one fired and in normal time returned to full brilliance. Through the entire test, lamp number two remained lighted and there was no evidence of any type to indicate possible ill effects on either lamp.

This test was repeated except that lamp number one was started cold after lamp number two had reached full brilliance. In this case, lamp number two went out. After a normal wait for the lamp to cool, it then restruck and came up to full brilliance.

All the foregoing tests show that at this point we have a constant-wattage ballast capable of operating one or two mercury lamps, either of which will operate independently, with no damage to either lamp when one lamp is on and the other is either operating, out or on restart. Now what happens when one or more lamps are added to this circuit? This does not mean a ballast specifically designed for two-lamp operation will operate satisfactorily for prolonged lengths of time with more than two lamps. In all cases, whether for two-, four-, or even ten-lamp operation it is assumed that the ballast is large enough to satisfactorily operate the total number of lamps under discussion.

Suppose that four lamps are operating at normal brilliance. If one lamp fails, the others will remain lit at about 95 per cent of normal brilliance. If a second lamp fails, the remaining two will stay lit at approximately 90 per cent of normal brilliance.

Similarly, if a ballast were made to operate ten lamps and one lamp failed, the other nine would remain burning with only a slight reduction in light output. In fact, as many as five out of the ten lamps could go out before there would be a 10 per cent reduction in watts to the remaining lamps.

Although it has been stated that this ballast is for the independent operation of individual lamps, in all fairness it must also be said that there is a small degree of interdependence of one lamp upon the other. This is explained in the diagram shown in Fig. 3. The ballast must be set up to operate in the range indicated by the shaded area. This is the range in which a large change in current produces a small change in voltage. This voltage change, however, is enough that reducing the load by 50 per cent will result in a 10 per cent reduction in the wattage delivered to the remaining lamps.

If the ballast were set up to operate one lamp at −10 per cent of rated wattage, and then nine lamps were added to the circuit, each lamp would be operating with +30 per cent of rated wattage. Conversely, if the ballast were set up so that all ten lamps were operating at rated wattage, and then nine lamps were extinguished, the remaining lamps would be operating at only 70 per cent of rated

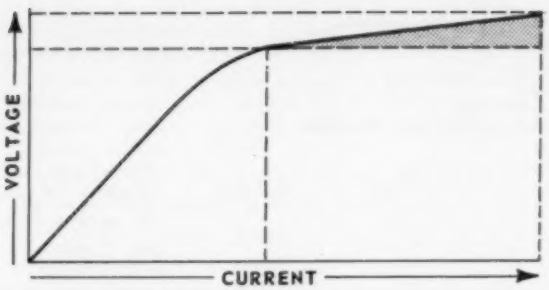

Figure 3. Typical current-voltage diagram showing operating range of secondary current (lamp current) and secondary voltage for constant-wattage circuits.

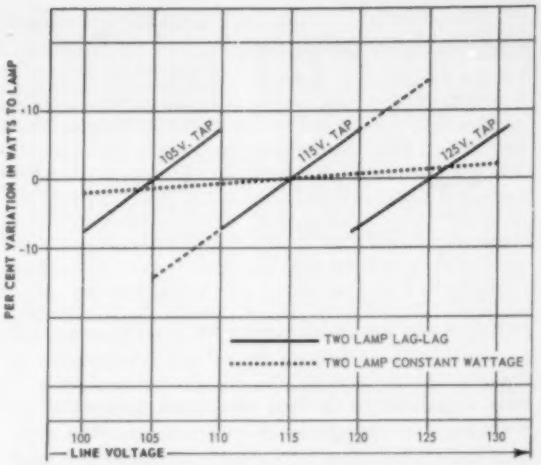

Figure 5. Typical regulation curve of a two-lamp lag-lag ballast with primary taps, compared to a two-lamp constant-wattage ballast without taps.

wattage. This could be a very unstable range in which to operate a lamp.

Practically, a ballast of this type should be limited to operation of the total number of lamps for which it is designed with a maximum allowable outage of lamps at any one time of one-half the total number in the ballast circuit. This should be satisfactory, since group replacement is designed to keep more than 50 per cent of the lamps in operation, and if individual burnout replacement is used, there is no problem.

Depending upon design centers, this ballast can be made to start the lamps in any required ambient temperature down to —20F. The particular ballast discussed here had an open circuit of 300 volts. With one lamp on and the other off, the voltage available to start a second lamp was 300 volts. With both lamps lit, the voltage available to start a third lamp was 320 volts. By extrapolating a curve through known figures, the prediction can be made that a ten-lamp ballast with the same parameters as the two-lamp ballast discussed in this paper would have 365 volts available to light a tenth lamp when only nine lamps are operating. See Fig. 7.

An interesting sidelight to this circuitry is that it can be set up to operate different lamps. For example, it could be made to operate one 400-watt lamp and one 250-watt lamp or two of each. The

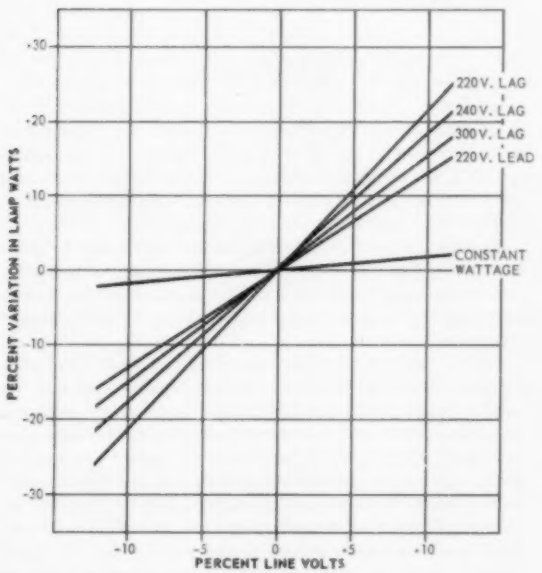

Figure 4. Graphical representation of lamp wattage regulation with variation in line voltage for typical mercury lamp ballasts.

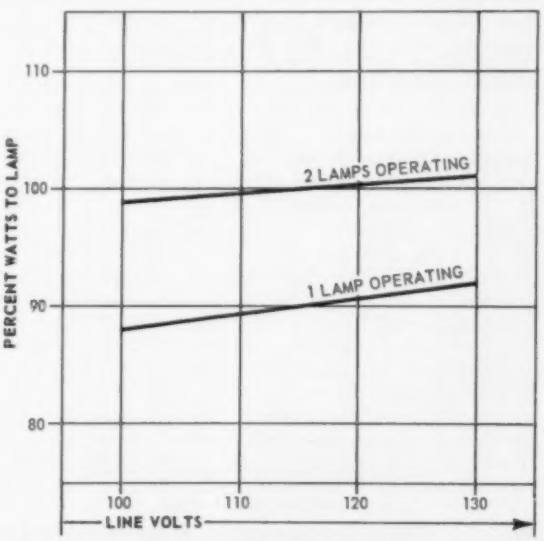

Figure 6. Measured regulation characteristic of a two-lamp independent lamp operation, constant-wattage ballast.

TABLE I — Comparison of Two-Lamp Ballasts.

Ballast A—Conventional Lead-Lag
Ballast B—Conventional Lag-Lag
Ballast C—Constant Wattage Series Type
Ballast D—Constant Wattage Independent Lamp Operation

Ballast	Independent Lamp Operation	Regulation	Regulation One Lamp Out	Taps Required	Power Factor	Power Factor One Lamp Out
A (Lead)	Yes	No	No	Yes	95%+	*48% Leading
A (Lag)	Yes	No	No	Yes	90%+	*42% Lagging
B	No	Yes	No	No	95%+	50-55% Leading
C	Yes	Yes	Yes	No	95%+	.....
D						95%+

*When one lamp is out, the line current will exceed or at least equal the current when both lamps are operating.

only requirement is that the rated operating arc voltage of the lamps must be the same. The problem most prevalent when using unbalanced loads is maintaining the 50 per cent minimum loading when lamp outages occur.

Comparison with Current Two-Lamp Ballasts

How does a ballast of the type discussed in this paper compare with two-lamp ballasts currently on the market? The main points of comparison have been enumerated in Table I, and it will be noted that the constant-wattage ballast performs favorably on all points. The constant-wattage ballast has regulation of ±2 per cent in lamp watts for a ±13 per cent change in line voltage. For ±5 per cent change in line voltage a lag-lag ballast will have a lamp wattage regulation of ±7½ per cent and the lead side of a lead-lag ballast will have a regulation of ±6½ per cent. Both the lead-lag and the lag-lag circuits give independent operation, but do not maintain high power factor with one lamp out. Tap changing is required for wide variation in line voltage.

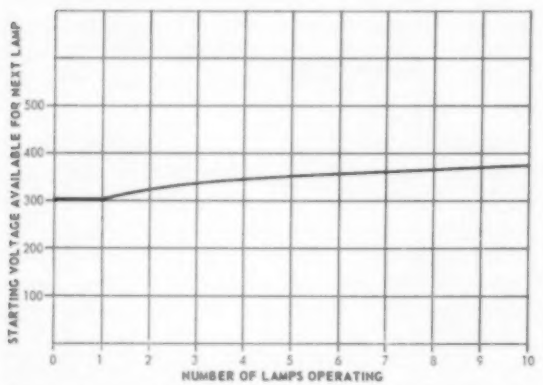

Figure 7. Graphical representation of the voltage available to start or restart each succeeding lamp. Note that at no point does the voltage available to start the lamps fall below 300 volts.

Another type that has been popular is the two-lamp constant-wattage ballast using either series lamps or series lamps with a sequence-starting capacitor across one lamp. These circuits both give the same regulation of watts to the lamp as does the ballast discussed in this paper, but neither gives independent operation of the lamp. If one lamp goes out, they both go out.

The popularity of two-lamp ballasts in the past has assured them a place in lighting. Does industry need a three-, four-, or more, lamp ballast? That is a question for which I do not have an answer. I do, however, have an opinion. If the lighting industry knows that a single ballast is available to light three, four, five, or any number of lamps that might prove practical for a particular installation, wouldn't they buy it? We all know that the lighting industry needes a two-lamp ballast. With the advent of the multi-lamp ballast, who knows what horizons may be opened.

DISCUSSION

K. M. SATHER:* The operation of several mercury vapor lamps from one constant wattage ballast is an interesting application of ballast design. The advantages of the constant wattage ballast, with its permissible broad variation in input voltage and elimination of taps, are apparent.

Mr. Olson's question regarding the need of industry for a ballast to operate several lamps provides a subject for some interesting speculation, particularly in view of the recent accelerated advancement in the design of mercury vapor luminaires and lamps.

The ballast described in this paper appears well-suited for applications which would involve a single luminaire designed for operation with two or more mercury vapor lamps. The introduction of "packaged" mercury vapor luminaires with self-contained ballasts raises the question of whether the installation of packaged units would be more economical, when all costs are evaluated, than the use of a single ballast where a single pole, two-luminaire installation is involved. Also, advancements in improving the starting characteristics of mercury vapor lamps may bring about an increased use of smaller reactors for various lamp sizes.

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R. D. CHURCHILL AND E. C. MARTT:* Providing that proper lamp operating requirements are met, the circuit proposed by the author appears to be practical.

One factor which is often overlooked when discussing "constant wattage" type ballasts is the variation in lamp wattage with lamp voltage, even though the ballast may be constant wattage with respect to changes in primary voltage. We would like to see data showing how lamp wattage varies with lamp voltage, since luminaire manufacturers say this wattage variation is of considerable importance to them.

Manufacturers of the proposed circuit should insist that the ballast be installed with the design number of lamps so that lamps would operate at normal ratings. If customers should install fewer lamps than specified, expecting later to add the full amount, then lamps on the partially-loaded ballast might not give satisfactory service. With the allowable number of outages, is enough current delivered to the lamps for proper warm-up under marginal conditions? Will the ballast meet the same minimum wattage (as proposed in ASA) as required for a single-lamp ballast?

We would like to see more engineering data on this circuit in regard to lamp current wave shape for starting and operating both with the normal number of lamps and with the allowable number of outages. We would also like to know how lamp starting current varies with the number of lamps on the circuit.

The trend in mercury lamps is to reduce the starting voltages at low temperature. If the open-circuit voltage of this ballast could be reduced, how would this affect lamp current wave shape, loading uniformity on lamps, and the number of allowed outages?

For the H33 lamps, wouldn't individual reactors operating from a well-regulated 240-volt line be as simple to install as the proposed circuit?

J. M. LAUGHLIN:* The author has clearly pinpointed the advantages of the circuit featured in his fine paper. However, some of the advantages are not unique to the circuit featured. Excellent regulation of lamp wattage with large changes in primary voltage, low-lamp current crest factor, high-power factor, and elimination of the need for primary taps are to be found in other mercury lamp ballasts using the latest advanced constant-wattage circuitry.

The unique advantage of the circuit featured is parallel lamp operation from a single constant wattage ballast. Let us deal with a specific example. An outdoor, weatherproof ballast utilizing the circuit featured in this paper achieves parallel operation of two 400-watt lamps in a relatively small package (12-5/16 inches high, 7-7/16 inches diameter—527 cubic inches—62 pounds). It has low losses (72 watts) and good efficiency (92 per cent).

However, there are two-lamp, 400-watt, constant-wattage ballasts that are even smaller (11¾ inches high, 6⅝ inches diameter—407 cubic inches—48 pounds) with comparable efficiency (91 per cent).

Granted, these smaller ballasts operate the two lamps in series, which in itself is not as desirable as parallel lamp operation. However, I shall leave it to the reader's considered judgment of subsequent disclosures whether trouble-free, series striking and operation of two lamps is not really preferable to interdependent parallel operation.

I was struck by the paper's lack of completeness in discussing the effect of commonly experienced field conditions. There is a most significant operating condition frequently encountered that is not acknowledged in this paper. What happens when there is a brief power interruption while the lamps are operating?

As is common to all mercury lamps used for general lighting applications, the lamps extinguish and will not restrike until the arc tube gas pressure has been reduced sufficiently by cooling to allow the lamps to hot-restrike. The cooling time required ranges from three to nine minutes. In the normal course of events, one lamp will hot-restrike first and start to warm up to full wattage. As much as six minutes later, lamp number two will hot-restrike.

My first observation of this condition on the subject ballast was this: when lamp number two did hot-restrike, lamp number one extinguished. Lamp number two then proceeded to warm up in the normal manner until lamp number one hot-restruck for the second time whereupon, lamp number two extinguished. This "flip-flop" continued for 43 hours and if the primary had not been disconnected would probably have continued until the lamps were destroyed.

This repetitive hot-restriking is especially damaging to the lamp. Part of the hot-restriking cycle is made up of a low current, high voltage glow discharge which persists for several minutes before the lamp is cool enough to make the transition to a full arc discharge. The very low glow discharge current will not bring the electrodes up to their normal state of thermionic emission. Instead, the high voltage of the glow discharge subjects the electrodes to destructive field emission.

Before and after photographs of the lamps subjected to 43 hours of "flip-flop" (approximately 215 hot-restrikes on each lamp) show that destructive end-blackening occurred.

The experience just described prompted observation of more lamps. A total of 21 lamps was observed during hot-restrike. They included lamps of the major manufacturers and both H1 and H33 lamps. If the lamps were put in two categories, stable and unstable (only with reference to their stability in the ballast circuit under consideration during hot-restrike), there would be lamps of all lamp manufacturers and both H1 and H33 included in the unstable category. Nine of the 21 lamps observed were unstable.

Obviously, "flip-flop" does not occur when two stable lamps are used together. When a stable lamp is paired with an unstable lamp, no difficulty is encountered if the stable lamp hot-restrikes first. But, if the unstable lamp hot-restrikes first, it will be extinguished only once, when the stable lamp hot-restrikes. Subsequently, both will warm up to full wattage normally. The only real difficulty occurs when two unstable lamps are paired. On the average, this should only happen about 25 per cent of the time. However, any single installation may not have the benefit of averaging lamps of several manufacturers, production lots, and types (H1 and H33). It could happen either way—none of the lamps or all of the lamps could be unstable.

Visualize the chaotic confusion prevailing in a plant, parking lot, or street lighting system when "flip-flop" does occur. There is, of course, a remedy—de-energize all primary circuits which have ballasts with "flip-flopping" lamps for approximately 15 minutes. In this way, all the lamps will cold-restrike simultaneously and warm up normally. Of course, if incandescent or fluorescent lighting were on the same circuit, this would of necessity be off also. It is, in the final analysis, the responsibility of the engineer specifying system components to properly evaluate the "flip-flop" phenomena. He must then decide in the best interests of himself and his client.

It is interesting that the circuit featured in this paper does have a completely trouble-free application in the lighting industry. In fact, it has been used for cold cathode fluorescent lamp ballasts for more than ten years.

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**Sola Electric Co., Chicago, Ill.

W. F. BLACKFORD:* I have been able to perform a limited amount of testing on a ballast of the type discussed in this paper. Unfortunately, the time prior to the scheduled presentation of the paper was not sufficient to permit as complete testing as might be desirable. However, some interesting phenomena were observed.

The paper describes tests in which one lamp was extinguished and then allowed to hot-restrike. The only unusual mode of starting reportedly occurred when lamp number two was up to full brilliance and then lamp number one was extinguished and allowed to hot-restrike. In this case, Mr. Olson stated that the operating lamp extinguished but after cool-down it restruck and came up to full brilliance. In my efforts to repeat this performance, I found that a "flip-flop" type operation often occurred, whereby lamp number two was extinguished when lamp number one struck, and then lamp number one extinguished when lamp number two restruck.

The method of making the above tests does not duplicate normal service conditions and was considered, perhaps, as being overly severe. The more usual cause of a mercury lamp outage is the loss of primary input voltage which would result in an outage of both lamps. When tests were performed to stimulate this condition, it was found that with some combinations of lamps the "flip-flop" type operation also occurred and sometimes for extended periods of time. With the limited testing that has been performed, no pattern has been established to indicate why some combinations of lamps cause alternate striking and extinction for extended periods while other combinations start and operate in a manner similar to that of two single-lamp ballasts.

It was noted that the second lamp to strike often would "hang in the glow" between the operating electrodes for an extended period of time before an appreciable arc current was established. It was also observed that the arc was often quite noisy during the warm-up period and that this noise often took the form of a high frequency tone, during which time the arc appeared quite unstable, when observed through Polaroid filters.

It appears that additional testing is in order to determine and eliminate the cause of alternate striking and extinction of lamps following an interruption in the power source. Abnormal cycling conceivably could have a detrimental effect on lumen maintenance and lamp life.

With the increased availability and popularity of mercury luminaires with integral ballasting, I am inclined to believe that the cost-saving advantage of the multi-lamp ballast over single-lamp ballast may be outweighed by the lower installed cost of the integrally ballasted type luminaires and their *completely* independent operation. Where installation and maintenance labor cost are given careful consideration, I believe that the integrally ballasted luminaire will prove to be more economical and popular than luminaires and external ballasts, whether of the single- or multi-lamp type. Undoubtedly, there will continue to be many applications where the use of individual luminaires and external multi-lamp ballasts will be advantageous.

J. PETERSON:** This paper presents some interesting performance data on a multi-lamp ballast. It would also be interesting to speculate as to how the circuit works. As an over-simplified statement, it appears that the secondary voltage of any high reactance transformer, when supplying a leading-type load, tends to be constant. Thus it is possible to connect capacitor ballasted lamps in multiple across the constant voltage secondary up to its rating and get regulated constant lamp current and hence constant wattage. The falling off of wattage on the remaining lamp of a two-lamp ballast when the other lamp is out should be the result of the reduction of leading load on the secondary. Leading load of a certain magnitude, of course, is necessary to develop the full regulating action of the over-all circuit. Would the author care to comment on this over-simplified explanation?

I note that the paper does not mention the use of peaking capacitors in the circuits. It seems to me that an economical design would need a peaking capacitor to start one of the lamps, especially if the lamps are not of the new easy-starting variety. The two-to-one ratio of secondary to primary mentioned on page 80 suggests that only 230 volts are available to start the first lamp. After the first lamp has started, I assume the secondary voltage will rise to start the remaining lamps due to the leading load offered by the first lamp that has started. This is indicated in Fig. 7.

V. W. OLSON:* I wish to thank Mr. W. K. Sather for his comments on my paper. To answer his questions on "packaged units," the packaged unit certainly will have some effect on this ballast; however, it will have an effect on all ballasting, not just the one discussed here. Only time can give us a proper evaluation on this.

I also wish to thank Messrs. Churchill and Martt for their interesting discussion and for their interest in the parameters of this unit. Time is not sufficient to give a complete rundown of all characteristics and magnitudes of currents and voltages of such a ballast; however, to hit a few high points, the starting current of the ballast is 4.2 amperes with a 50 per cent load and 4.7 amperes with a 100 per cent load. Crest factor of the lamp current is 1.9 at a 50 per cent load and 1.68 with a 100 per cent load. Considerable testing is going on in this circuitry and when information is available we will pass it on.

As to the last paragraph on H33 lamps ("... wouldn't individual reactors operate as well on a well-regulated line?"), there is no argument about that; however, the line must be well-regulated since in order to maintain plus or minus two per cent wattage to a lamp, line voltage must be kept at 240 volts plus or minus one per cent.

I will discuss Mr. Blackford's and Mr. Laughlin's comments together as they are quite similar. It is interesting to note that they both came up with reasons for their comments by measuring a ballast built to this circuitry. This ballast will cycle under a very special set of circumstances. We have known of this but have minimized it because until recently lamps we had tested had never exceeded three cycles and we felt this to be insignificant. In a more recent survey, after examining a total of 52 lamps from six different manufacturers, we came up with the following:

Twenty-four sets or 48 lamps had no tendency to cycle. One set cycled once and one set evidenced the same effects as the lamps mentioned by Mr. Laughlin in that they continued to cycle continuously. Careful examination of these lamps showed that they were rather old lamps and had been subjected to quite rigorous laboratory testing, and there is no way of indicating what lamp life was left. The arc tubes had severe end blackening. We must admit the situation will exist provided a pair of lamps evidence long hot-restrike time and fast warmup. It is interesting to note that both old and new lamps were tested and we got no

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*Author.

cycling on any new lamps or on any H33 lamps. Using simple arithmetic, the tests we ran would indicate that the chances for such an occurrence would be four per cent rather than the 25 per cent indicated by Mr. Laughlin. But if you take into account the odds against picking the particular two, out of a random lot of 52, that would evidence this characteristic, the percentage would drop nearer to 0.2 per cent and even this would not be evidenced until appreciable aging had changed the lamp characteristics.

Furthermore, to the best of our ability, we find that momentary outages are not a large factor in outdoor lighting. If it were a common occurrence, I am sure the trend would be away from mercury lighting rather than towards it. The outages of five minutes or more would not produce this effect. Even if one pair of lamps would start cycling some evening, as soon as the lamps shut off in the morning the condition would be cured. On restriking, the following evening, the condition would not reoccur.

The time allowed me does not permit lengthier or more detailed discussion of this phenomena. Field testing alone, on ballasts built to the circuitry of my paper, will show up the percentage of lamps manufactured with the odd characteristics required to produce this effect.

I thank Mr. Peterson for his rather interesting comments on the operation of this ballast. I agree that his concept may be a little over-simplified but I do not think it is an incorrect statement. He is quite correct; we did use a peaking condenser to get the initial open-circuit voltage.

Designing Low Brightness Luminaires For Higher Lighting Levels

(Discussion and rebuttal of a paper by Q. D. Dobras and D. R. Phillips, published in October, 1959 ILLUMINATING ENGINEERING.)

B. F. JONES:* The stated objectives of this louver design are to minimize louver brightness in the shielded zone and to provide good lighting efficiency. If there is to be a criticism of this design, it must be that in the achievement of the first objective, the authors succeeded too well. My comments, therefore, will be directed mainly toward ways in which this louver is likely to be misused.

The purpose of a lighting system is to provide proper conditions within an area for the performance of visual tasks within that area. Too often, in the process of designing lighting for such an area, one aspect is given primary consideration, to the detriment of all the other aspects which go to make up the complete set of visual conditions. For example, we have all seen installations in which room surface reflectances were not considered at all in designing lighting for a room, though they constitute by far the majority of the visual field.

It is, therefore, instances in which this louver may be used to obtain very low brightness and high flux concentration as ends in themselves, rather than as means to the end of proper visual conditions, that concern me. Both these features can militate against achieving desired conditions.

Using this louver under the conditions described in Tables II and III, the ceiling will have a brightness of about 15 per cent of the task brightness, considering a task of 80 per cent reflectance. This is of the same magnitude as the floor brightness, and is well outside the 3:1 considered desirable. If the floor reflectance were 30 per cent, the ceiling could well be the lowest brightness surface in the room. This produces an environment in which the brightness patterns of the visual field are inverted, compared to our usual conditions. I was in a room with a black louverall ceiling and it wasn't very pleasant.

From a brightness ratio standpoint, it would be preferable to have the ceiling brightness within the direct glare zone about half to three-fourths as bright as the task, in which case the configurated clear plastic system (which is also about 20 per cent more efficient in footcandles) might be preferable. The installation shown in Fig. 13, incidentally, is one in which most of the tasks performed are low-reflectance, so contrast with the ceiling is closer to 3:1 than would be the case in an office.

Are concentrating distributions always preferable? I doubt it. Under these conditions it is often difficult to get proper brightness ratios, particularly when the walls and other vertical surfaces are concerned. Even in industrial lighting the trend is toward more diffuse systems, which produce fewer shadows, better illumination on the vertical, and more comfort.

Using a spread (semi-diffuse) finish on the louvers gives both better brightness ratios within the room and better diffusion to the system. With proper control, this louver design should be a valuable tool for obtaining excellent direct-view visual conditions within rooms.

One other point must be considered, however. The system does not control reflected glare. Recent research has indicated the great importance of proper control of reflected glare on our visual conditions. Of the systems compared in Tables II and III, only No. 1—diffuse plastic sheet—is acceptable in this regard, and this system is highly deficient from a direct glare standpoint. The wedge louver system, though, has the characteristic of practically uniform louver brightness at angles outside the shielding angle, and if used with a uniformly luminous ceiling above it, would provide excellent control of both direct and reflected brightnesses. This might best be obtained by using a cavity illuminated by indirect means, with this louver system suspended below it. With the louver surface characteristics controlled to give a louver brightness within the shielded zone of 50 to 100 per cent of the task brightness and

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proper room surface reflectances such a system should provide almost perfect visual conditions.

D. E. SPENCER: Given the criteria suggested by the authors, the results presented in the paper are correct. The geometric principle is similar to that employed in my paper on controlled fluorescent light[1] except that here the source is the region between two parallel lines rather than a single fluorescent lamp. Thus, the *parabola* is the suitable reflector contour, rather than a *macrofocal conic*.[2]

For the reflector design problem treated in the paper, accurate data are needed on the diffuse and specular reflectances of the louver surface. A complete analysis of the distribution of light beyond the cut-off plane is not otherwise possible. Here is another example in which goniophotometric reflectance measurements[3] are needed.

However, the really serious difficulty with this paper is the fundamental criterion on which it is based. It is probable that luminaires with wedge-shaped louvers will be grossly misused in applications.

In the development of the criterion, the authors have entirely neglected reflected glare, but specular wedge-shaped louvers are potent sources of reflected glare and at the lighting levels which are to be used in the near future, the reflected image of a fluorescent lamp is deleterious to vision. Louvered lighting, even with the ingeniously designed louvers described in this paper, is still not quality lighting for any application in which reflected glare can be observed.

1. Spencer, D. E.: "Controlled Fluorescent Reflector Design for Sharp Cut-Off and Uniform Distribution." ILLUMINATING ENGINEERING, Vol. LIV, No. 3, pp. 167-174 (March 1959).
2. Spencer, D. E. and Montgomery, L. L.: "Macrofocal Conics as Reflector Contours," to be published.
3. Spencer, D. E. and Gray, S. M.: "On the Foundations of Goniophotometry," a paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif.

R. D. BRADLEY:** This is a most interesting paper, pointing up some principles which, while not new in concept, are new in their relative importance. The parabolic section for downward light control is not a new idea, as witnessed by cross louvering of units by parabolic sections imposed upon a flat plane. The novel part of the paper is that the authors point out that louver brightness can be controlled by the brightness of the room surfaces.

The authors have done an excellent job of presentation and explanation of data. They have been practical in presenting working data using several types of reflectors and in establishing comparisons with other types of shielding or louvering media.

The question arises as to what the comparative results would be if the user did not want or need 500 footcandles. Fig. 9 shows four lighted panels in a black ceiling, which I realize is not true. However, our greatest problem from an appearance standpoint and perhaps from a comfort standpoint as well, has been to get the brightness of this type of louver *up, not down*.

Data presented show a relationship at the higher angles of about 10:1, comparing task brightness to louver brightness. Assuming that relatively large ceiling areas are involved, this may not give a pleasing appearance. The authors have pointed out that the distribution from this type of louver cell is rather concentrated. This can also be a problem under conditions requiring lower intensities from the higher output sources.

Table II gives some very interesting comparisons. It would have been helpful to the fixture designer if some data could have been presented on grids of rather close cell size, or if data on the specular wedge having approximately ½- by ½- by ½-inch measurements were included.

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**Day-Brite Lighting, Inc., St. Louis, Mo.

Q. D. DOBRAS and D. R. PHILLIPS:* The discussers have raised several interesting points concerning the design and application of this wedge louver. It was pointed out that the wedge louver makes it possible to have the brightness of the task lower than the brightness of the ceiling. While this brightness relationship may seem strange or "inverted" to the observer, it does not follow that this will have an adverse effect on visual comfort. Matthew Luckiesh in his book, *Light, Vision and Seeing*, points out that the desirable brightness in the peripheral field should be, "(1) Less than 100 per cent, and (2) Greater than 10 per cent of brightness of central field." The peripheral field is defined as the visual field outside a central 60-degree cone and would include much of the ceiling area in a large space. At 1000 footcandles the brightness of the wedge louver grid is typically 120 to 160 footlamberts in the shielded zone. Even with a 50 per cent reflectance task (which is high for most industrial tasks) the ratio of 150 footlamberts ceiling brightness to 500 footlamberts task brightness is within the desirable range. Most other louver types would have a higher brightness than the task. This is not necessarily more desirable from a comfort standpoint and brightnesses in the peripheral field greater than the task may actually be undesirable.

Reflected glare is an important consideration in visibility and visual comfort. One of the more effective means of reducing reflected glare is to reduce the specularity of the task or to change the angular placement of the task so that the reflected image of the source is directed out of the field of view. Where these changes are not practical or possible, it is desirable to have the reflected image of the light source as low in brightness as possible. In the shielded zone the brightness of wedge louvers is extremely low; therefore, a reflected image of the louvers between the shielding angle and 90 degrees would not be bothersome regardless of the lighting level. Below the shielded zone a direct view of the lamps and cavity can be reflected in shiny surfaces. The average brightness of fluorescent lamps is 2100-5000 footlamberts depending upon the lamp type. At 1000 footcandles the cavity brightness approaches lamp brightness since lamp spacing is very close. Measurements indicate that a uniform brightness luminous ceiling supplying 1000 footcandles would have brightnesses of 1500-2000 footlamberts between 90 degrees and nadir. It is questionable whether a marked improvement in visual comfort will result from this reduction of maximum brightness in the non-shielded zone, particularly in view of the increased brightness in the remaining ceiling area compared to the brightness of wedge louvers.

If the brightness of the wedge louver proves to be too low it is a rather simple matter to increase brightness by making the louver surfaces more diffuse. This fact is illustrated in Fig. 13 of the paper.

The parabolic wedge louver is suggested as an answer to brightness problems that will certainly occur as lighting levels increase. The authors hope that this paper will aid in the design of lower brightness luminaires and stimulate new ideas for improved luminaire brightness control. Not all applications require 500 footcandles or more, but for the many visual tasks that do, we should be prepared to supply the needed illumination efficiently and comfortably. The wedge louver is one way this can be done.

*Authors.

Improved Mercury Lamp Transformer for Maximum Regulator Loading on Series Circuits

Constant current regulators can be worked nearer capacity by taking advantage of cascade starting of mercury lamps and by using a new insulating transformer design.

By M. E. ROBERTSON

ONE OF THE most important factors in street lighting today is cost, both initial and operating. This fact, when applied to mercury street lighting, leads to a discussion and comparison of multiple circuits versus series circuits. It is not the intent of this paper to discuss the relative merits and costs of these two systems. It is sufficient to say that series circuits are still very much a factor in street lighting and that in new installations, about one out of ten is a series circuit.

The purpose of this paper is to demonstrate that lower cost series mercury installations are practical as a result of heavier constant current regulator loadings, made possible through new insulating transformer designs. The over-all economics of straight mercury lamp series circuits as compared to mercury lamp series circuits using insulating transformers will not be made. However, many of the factors will be discussed.

Operation of the Series Circuit

Series circuits are advantageous in that long runs can be made with small wire sizes, simplified control can be used, maintenance costs are lower, and close regulation of lamp watts is automatic. This is not the whole story, however, since series circuits also have very high voltages, the series loop must be maintained or all lamps go out, and a relatively high cost constant current regulator is required.

In operation a constant current is maintained through a series loop by the constant current regulator. A sufficiently high voltage must be available to start and operate all lamps in series. Unlike a multiple system, the current is held constant and the voltage is varied to meet the load requirements. This is accomplished by means of the moving coils on the regulator. Before the circuit is energized, the regulator coils are resting together, but as soon as the primary of the regulator is energized, the coils fly apart and adjust themselves to whatever position is required to maintain rated current in the series loop. If too high an impedance is included in the series loop, the coils will come together and the output current will drop below the rated value which is most often 6.6 amperes. At the loading which causes the coils to just touch, the voltage will be at a maximum. The regulator coils will automatically change position to maintain rated current through the load.

Most of the newer regulators of the pole type are designed to have 50 per cent minimum impedance. This means that if the secondary is shorted through an ammeter, rated current will flow with one-half of rated voltage applied to the regulator whose coils will just be touching. Older regulators may have minimum impedance of higher than 50 per cent. Typical values for these are 56.5 per cent and 63.6 per cent.

The pole type constant current regulators are designed to regulate the series current within plus or minus one percent, with a line voltage variation of plus or minus five per cent. They will deliver rated output at 95 per cent line voltage with a 99.5 per cent power factor load. This means that a 50 per cent impedance regulator will deliver a maximum of 113 per cent of rating at nominal line voltage and unity power factor load, according to regulator manufacturers.

Advantages of Using Insulating Transformers

Series operation of mercury transformers can be and is accomplished successfully without insulating transformers. Such an installation is called a straight series system. With this system a special 3.2-ampere constant current regulator or a 6.6-ampere lamp must be used, as well as a time delay relay.

A mercury vapor lamp does not provide a path for the current until after the lamp has started and the arc between the main electrodes has been established. A means of shorting out a faulty lamp must

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHOR: Jefferson Electric Co., Bellwood, Ill.

be used or none of the lamps will start. This can be accomplished by using film cutouts or a special lamp with a built-in fail shorted device. A time delay relay must be incorporated in the straight series circuit to prevent the high voltage from being applied to a hot, unstartable lamp after a momentary line interruption, or else the lamp shorting device will be actuated.

A starting voltage of 290 volts for an H1 or 230 volts for an H33 lamp is required for —20F starting on a multiple circuit. On a straight series circuit starting voltages of this magnitude are required for cold weather starting, and the regulator must provide this voltage across each lamp. This places a definite limitation on how many lamps can be used on a given regulator.

The high voltage series circuit must be carried up the pole and into the luminaires. More expensive luminaires must be employed to withstand this high voltage. A safety hazard exists to workmen who are relamping or cleaning luminaires and extreme caution must be used to make sure that the system is positively shut down.

The use of an insulating transformer for each lamp eliminates these shortcomings, since its primary provides a positive path for the series current and its insulating property keeps the high voltage off the luminaire. The series loop will be maintained even with one or more unstartable mercury lamps. Insulating transformer designs are available to provide 3.2 amperes to standard lamps from any value of series current whether it is 6.6 amperes or 20 amperes. This provides positive starting and allows the use of cascade starting of lamps, resulting in more lamps per regulator.

Cascade Starting

The concept of cascade lamp starting with insulating transformers on series mercury lamp circuits was described by W. A. Zander.[1] The cascade lamp starting principle is based on two characteristics of the mercury lamp. The voltage across a mercury lamp is drastically reduced upon starting and in any random group of mercury lamps some will start at a much lower voltage than others. In a given installation, if a sufficient number of insulation transformers and lamps are used as a load on the constant current regulator, the regulator will be overloaded and the open circuit voltage will drop. Insufficient voltage will be available to start all of the lamps immediately in cold weather; however, there will still be enough voltage to start the first or easiest starting lamp. This voltage can drop appreciably below that recommended for multiple circuits. At least one utility has found that this voltage can be as low as 170 volts for —15F starting. A value of 200 volts would be more conservative for H1 lamps and would be quite adequate for H33 lamps.

To continue with the cascade starting principle, the first, or easiest starting lamp will start and as soon as it does its voltage drops to a very low value, thus providing more voltage to the remaining lamps. The second lamp starts, again providing more voltage for the remaining lamps. This process continues on through the group of lamps with more and more voltage being available for the harder starting lamps until all lamps have started. The cascade starting principle is involved in the starting of mercury lamps on the various insulating transformers which will be discussed.

TABLE I — Input Characteristics of Large Gap, Minimum Gap and Optimum Gap Insulating Transformers Under Open Circuit and Operating Conditions at 6.6 Amperes.

Lamp Operating	Large Gap	Minimum Gap	Optimum Gap
Input kva	.510	.462	.472
Input kw	.433	.430	.430
Power Factor	85	93	91
Open Circuit			
Input kva	1.19	1.48	1.32
Input kw	.08	.084	.084
Power Factor	6.7	5.7	6.3

Loading the Regulator

The basic problem of loading a constant current regulator with a mercury lamp load is that sufficient voltage must be provided to start all of the lamps and sufficient power must be available to operate the lamps. Consider the maximum number of lamps which can be used on a 25-kilowatt regulator of the 50 per cent impedance type when using insulating transformers of the large gap variety. These transformers have a loss of approximately 33 watts so the input, from Table I, while operating a 400-watt lamp in a horizontal position, is 433 watts at 85 per cent power factor. The input will be .510

TABLE II—Relation of Maximum kva Capacity at Rated Secondary Current to Secondary Load Power Factor (Mathematically Derived Curves).[1] 50 Per Cent Minimum Impedance Regulator.

Load Power Factor	Maximum kva Capacity In Per Cent of Rated kw
65	76
70	77.5
75	79
80	82
85	86
90	91
95	98

kva. The 25-kilowatt regulator must be derated to 86 per cent or 21.5 kilowatts at 85 per cent PF, in accordance with Table II. At this loading the regulator could operate 42 400-watt lamps; however, no allowance has been made for lamp outages, line voltage variation and circuit losses. Some assignment to these values must be made in order to arrive at a practical loading point.

Generally, circuit losses are primarily due to the watts loss in the cable. A factor of .02 kilowatts for number 6 and .03 kilowatts for number 8 copper wire per 1000 feet is common practice. These figures become .03 and .04 for steel armored cable. If we allow 150 feet of number 8 armored cable per lamp the losses will amount to only six watts per lamp and are not a major factor on a mercury circuit.

A very important factor is lamp outages. From Table I it is evident that the input kva increases to 1.19 at 6.7 per cent power factor for an open-circuited conventional large gap transformer. An allowance of ten per cent of the lamps being out at one time (due to lamp failure, end of life and breakage) seems to be a practical maximum value. When ten per cent lamp outages and six watts per lamp circuit losses are factored in, the load power factor drops to 74.5 per cent at .542 kva per lamp. The regulator has to be derated to 78.6 per cent at this power factor, giving a load factor of .69 kilowatt per lamp.

In addition to the above, allowances for line voltage variations must be considered. However, since five per cent allowance has already been factored into the design of the regulator, no additional allowance need be made.

The regulator will still regulate and the system function properly with ten per cent of the lamps out, with the primary voltage on the regulator being five per cent low. These safety factor allowances are debatable, but seem to be practical workable allowances and will be applied to the other insulating transformers which will be discussed.

Returning to the example: The 25-kilowatt regulator will handle 36 400-watt lamps and the regulator will be carrying a lamp load of 14.4 kilowatts, or 57.5 per cent of its capacity.

The discussion thus far has considered the problem only from the standpoint of the loading on the regulator. The starting condition must also be considered. From Table I it is evident that the large gap insulating transformer with 6.6 amperes through its primary will have a power factor of approximately seven per cent and a voltage of approximately 180 volts, before the lamp starts. The input kva is 1.19. Thirty-six lamps would place a load of 43 kva on the 25-kw regulator. The regulator will be overloaded and will be unable to maintain its rated 6.6-ampere current through the load. The load current will drop, and the regulator coils will be tight together.

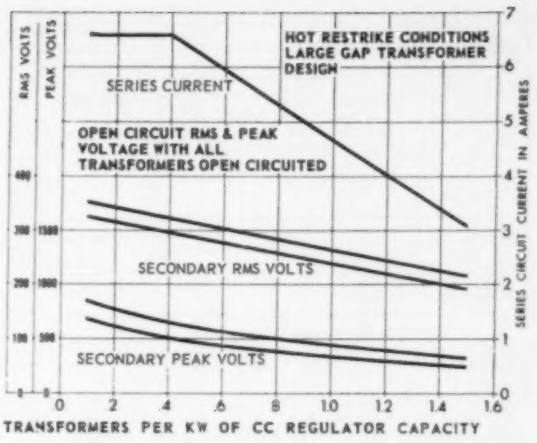

Figure 1.

The available starting voltage under these conditions has been determined by test. Fig. 1 shows the loading on a ten-kilowatt regulator having 50 per cent minimum impedance. The abscissa is plotted in the number of insulating transformers and lamps per kilowatt of regulator capacity, the reciprocal of the more common term of regulator capacity required per lamp. A better spread of data and a more readable curve result from this method of plotting.

Fig. 1 is a plot of the test results obtained by loading a ten-kilowatt regulator with a varying number of insulating transformers and 400-watt lamps. The lamps were allowed to operate for at least ten minutes, then the circuit was momentarily interrupted and readings taken before the lamps could restrike. A random group of transformers and lamps was used. Test data were taken on the lowest and highest transformers in the group. This is represented by the double line on the graph, the lower line being the lowest transformer and the higher line being the highest transformer. For each group of transformer tests (1-15 units), the series loop current, the insulating transformer's peak and rms open circuit voltage were measured.

In the previous example, the possibility of using 36 400-watt lamps on a 25-kilowatt regulator was discussed. This amounts to 1.45 insulating transformers per regulator kilowatt. Fig. 1 shows that at this loading the rms voltage will be 195-210 volts. This is, of course, at nominal line voltage and with very low circuit losses. The peak voltage at this point is only 250-300 volts, indicating a crest factor below that of a sine wave.

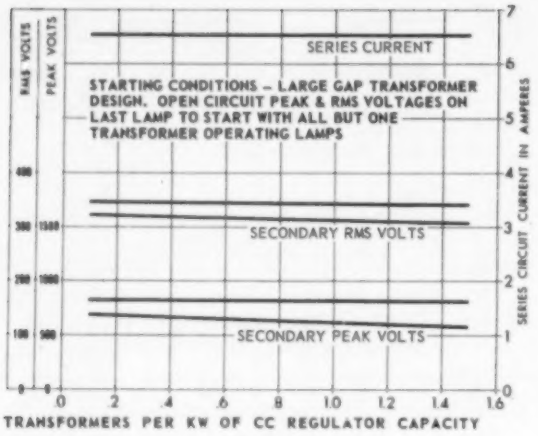
RMS VOLTS
PEAK VOLTS
SERIES CURRENT
STARTING CONDITIONS – LARGE GAP TRANSFORMER DESIGN. OPEN CIRCUIT PEAK & RMS VOLTAGES ON LAST LAMP TO START WITH ALL BUT ONE TRANSFORMER OPERATING LAMPS
SECONDARY RMS VOLTS
SECONDARY PEAK VOLTS
SERIES CIRCUIT CURRENT IN AMPERES
TRANSFORMERS PER KW OF CC REGULATOR CAPACITY

Figure 2.

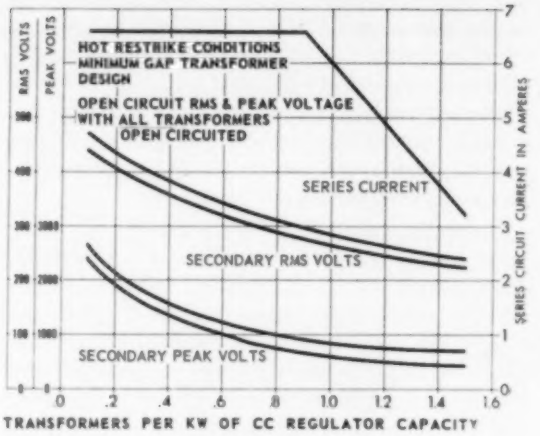
RMS VOLTS
PEAK VOLTS
HOT RESTRIKE CONDITIONS MINIMUM GAP TRANSFORMER DESIGN
OPEN CIRCUIT RMS & PEAK VOLTAGE WITH ALL TRANSFORMERS OPEN CIRCUITED
SERIES CURRENT
SECONDARY RMS VOLTS
SECONDARY PEAK VOLTS
SERIES CIRCUIT CURRENT IN AMPERES
TRANSFORMERS PER KW OF CC REGULATOR CAPACITY

Figure 3.

The test data indicate that a loading of 1.45 lamps per kilowatt would be acceptable, especially when both a random group of lamps and a random group of transformers are considered. At this point, the series current is 3.3 amperes. This current would not trip an open circuit protective relay set at 3.2 amperes. Incidentally, open circuit protective relays with 2.5-ampere trip settings are now available from at least two manufacturers.

Fig. 2 represents a plot of test data on the same basis except that here the data are taken on the last lamp to start. All transformers are operating lamps which have just started except the transformer under test which is open circuited. Fig. 2 shows that rms voltages of 300-340 and peak voltages of 600-800 are available for starting the last lamp at loadings of 1.45 lamps per kilowatt. This is adequate for starting either H1 or H33 lamps at —20F. A comparison of Fig. 1 (all transformers open circuited) and Fig. 2 (only one lamp open-circuited) illustrates the process of cascade lamp starting.

From the above it appears that from both regulatory capacity and lamp starting viewpoints, it would be practical to load a 25-kilowatt regulator with 36 lamps when large gap insulating transformers are used.

The Minimum Gap Design

In order to improve the regulator loading, a new design approach to the insulating transformer has been investigated. It is apparent that if the power factor of the insulating transformer can be improved, more lamps per regulator can be used. The obvious way to improve the power factor is to lower the primary voltage of the insulating transformer, since the current and lamp watts must remain constant. The conventional large gap insulation transformer has high internal leakage reactance and a primary to secondary turns ratio of about 1.83 is required to provide proper lamp wattage.

An insulating transformer design having a minimum gap and minimum leakage reactance was made and tested. This approach allows a turns ratio of approximately two. Table I shows that the kva input becomes .462 and the input power factor improves to 93 per cent, which is practically that of the lamp alone. If allowance is made for ten per cent lamp outages and circuit losses, the lamp factor is .61 or 1.64 lamps per regulator kilowatt.

The minimum gap design allows the use of 41 lamps on a 25-kw regulator. Because of the high turns ratio and low leakage reactance, sufficient voltage is available to start the first lamp. This has been determined by test, as shown in Fig. 3. Extrapolation shows that 220-230 rms and 500-700 volts peak are available for starting the first lamp.

Fig. 4 shows the minimum gap transformer for

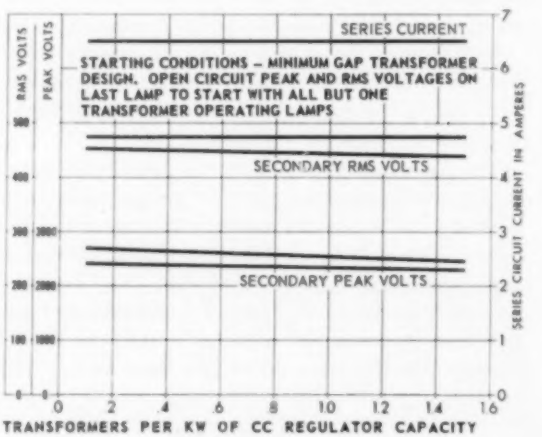
RMS VOLTS
PEAK VOLTS
SERIES CURRENT
STARTING CONDITIONS – MINIMUM GAP TRANSFORMER DESIGN. OPEN CIRCUIT PEAK AND RMS VOLTAGES ON LAST LAMP TO START WITH ALL BUT ONE TRANSFORMER OPERATING LAMPS
SECONDARY RMS VOLTS
SECONDARY PEAK VOLTS
SERIES CIRCUIT CURRENT IN AMPERES
TRANSFORMERS PER KW OF CC REGULATOR CAPACITY

Figure 4.

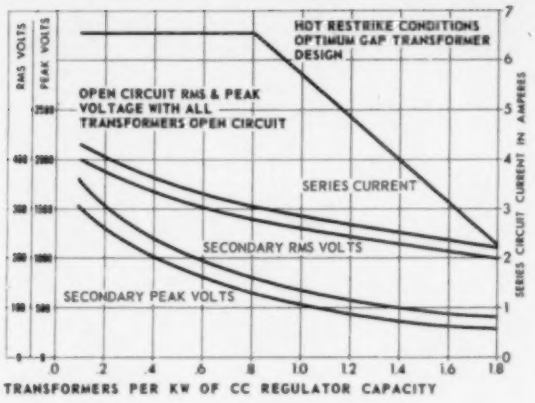

Figure 5.

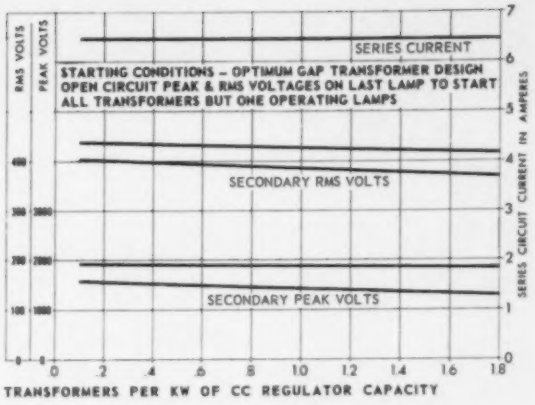
RMS VOLTS
PEAK VOLTS
SERIES CIRCUIT CURRENT IN AMPERES
SERIES CURRENT
STARTING CONDITIONS – OPTIMUM GAP TRANSFORMER DESIGN
OPEN CIRCUIT PEAK & RMS VOLTAGES ON LAST LAMP TO START
ALL TRANSFORMERS BUT ONE OPERATING LAMPS
SECONDARY RMS VOLTS
SECONDARY PEAK VOLTS
TRANSFORMERS PER KW OF CC REGULATOR CAPACITY

Figure 6.

various regulator loadings, with all transformers but one operating lamps. The conditions for starting the last lamp are: At 1.65 transformers per kilowatt, 445-480 volts rms and 2300-2500 volts peak can be expected. The series current is 6.6 amperes. Recently proposed ASA specifications limit the open circuit voltage to 2150 volts peak and 450 rms for a 400-watt mercury lamp. In view of these specifications, unless the proposed ASA values are increased, the minimum gap transformer cannot be utilized, even though most of the lamps on the market will withstand these voltages.

The Optimum Gap Design

Once the limitations on a large gap and minimum gap transformer have been shown, the next step is obviously the optimum gap transformer with low leakage reactance.

Table I shows that the optimum gap transformer has a power factor of 91 per cent and an input of .472 kva. Allowing for circuit losses and for ten per cent lamp outages, the input becomes .505 kva at 79.3 per cent power factor. The regulator must be derated to 81.8 per cent at this power factor, giving a lamp factor of .62 kilowatt per lamp or 1.61 transformers per kilowatt. This allows 40 lamps on a 25-kilowatt regulator.

TABLE III—Constant Current Regulator Loading for 50 Per Cent Impedance Regulators for 400-Watt H1 or H33 Mercury Lamps with Insulating Transformers. Allowance has been made for 10 Per Cent Lamp Outages and Six Watts Per Lamp Circuit Losses. Cascade Lamp Starting Is Utilized.

	Number of Lamps				
Regulator Rating	10	15	20	25	30
Large Gap Transformer (Factor .69)	14	22	29	36	43
Optimum Gap Transformer (Factor .62)	16	24	32	40	48

Fig. 5 shows the test data curves for various regulator loadings. At 1.61 transformers per kilowatt, the open circuit voltage to start the first lamp will be 350-450 volts peak and 210-230 volts rms, sufficient voltage to cascade start H1 lamps in cold weather and most ample voltage for starting H33 lamps down to —20F.

The series current has dropped to three amperes at this loading point, which should cause no difficulty with open circuit protective relays having trip values of 2.5 amperes. Most series circuits do not use open circuit protective relays. However, if the older 3.2-ampere trip relay is used, a lamp factor of .667 kilowatts is recommended.

Fig. 6 shows the voltage available for starting the last lamp. At 1.61 transformers per kilowatt, it is 375-415 volts rms and 1300-1800 volts peak. This is certainly adequate for starting any 400-watt lamp capable of starting and is also well within the proposed ASA specifications.

The optimum gap transformer meets all of the requirements. It allows more lamps per regulator and yet provides adequate cold weather starting voltage for the first lamp and a safe starting voltage on the last lamp to start. The gains in increased regulator loading of the optimum gap over the large gap transformer are diminished by the cascade starting principle and the advent of the easier starting H33 lamp. The large gap transformer provides only 195-210 volts for starting the first lamp at a lamp factor of .69. This is questionable for starting H1 lamps in very cold weather, but is adequate for H33 lamps. The optimum gap transformer provides ten per cent more voltage (210-230 volts) for starting the first lamp and is, therefore, preferable. The better lamp factor of .62 for the optimum gap transformer is also a plus value, since it makes lower cost series circuits possible.

Summary

Table III shows a comparison between the large gap and optimum gap units. The gain in loading of the new design over the old is ten per cent more lamps per regulator, which is very worthwhile. The allowance for ten per cent of the lamps being out greatly reduces the maximum number of lamps per regulator. If film cut-outs were used, the non-operating lamps would be shorted out and would not add to the regulator loading. A time delay relay would also be required. Under these conditions, the optimum gap transformer with ten per cent safety factor allowance for line voltage variation and circuit losses could be applied with a lamp factor of .57, allowing 44 lamps on a 25-kilowatt regulator. Whether or not the additional four lamps would justify the cost of adding the film cut-outs and the time delay relay is beyond the scope of this paper. Heavier regulator loadings could also be achieved if the system were maintained at a maximum of five per cent lamp outages.

It has been demonstrated that more mercury lamps per regulator are possible through this approach to insulating transformer design and that under the same conditions the new optimum gap unit permits heavier regulator loading than the older large gap transformers. This makes lower cost mercury lighting on series circuits practical and possible.

Reference

1. Zander, W. A.: "More Series Vapor Lamps per Transformer," *Electric Light and Power*, p. 94, September 15, 1956.

DISCUSSION

W. F. BLACKFORD:* This paper and the work behind it has undoubtedly stimulated much interest in constant current regulator loadings and has brought forth from the files of the regulator manufacturers characteristic curves for their regulators. These have previously been available, but not too widely distributed. Regulator characteristic curves are now available to lighting engineers who wish to design their constant current circuits to utilize the maximum load capabilities of the equipment being used. To this end, it would be desirable if all manufacturers of series mercury transformers would provide information on their designs, such as is given by Mr. Robertson in Table I and Figs. 1 to 6 inclusive.

The paper infers that on the straight series circuit the total voltage provided by the regulator on starting must be equal to the number of mercury lamps times the voltage required to start each lamp on a multiple ballast at any given temperature. Our tests on the straight series uni-ballast system have shown that a cascade action can also occur with this type of system, which assists in starting lamps down to –20 or –40F with reliability when the average voltage available per H1 400-watt lamp is as low as 190 volts rms.

*Line Material Industries, South Milwaukee, Wis.

TABLE A.

Load Power Factor Per Cent	Maximum kva Capacity In Per Cent of Rated kw	Load kw Per Cent Rated kw
65	76	49.4
70	77.5	54.3
75	79	59.2
80	82	65.6
85	86	73.0
90	91	81.9
95	98	93.0
100	113	113.0

The open-circuit voltage of a regulator is a function of the regulator design and the input voltage. The voltage available from the regulator and impressed across a group of 1IH transformers usually will be less than the open-circuit voltage. I believe the author meant this available starting voltage rather than the open-circuit voltage in his discussion of cascade starting. I concur that a value of 200 volts rms per lamp should be a reasonable minimum starting voltage for either H1 or H33 type lamps, where cascade starting can be anticipated, as in a constant current powered circuit.

Luminaire design should be such that maximum protection is provided from exposed high voltage parts during normal maintenance operations. This consideration applies not only to direct series luminaires, but also to those where the transformer is integral with the luminaire or where the peak open-circuit voltage approaches 2000 volts, as in many designs of low gap transformers.

I believe that it has been the general practice in the outdoor lighting industry and among moving coil regulator manufacturers to express the effect of load power factor on the load capabilities of this type of regulator as a percentage of kw regulator rating. Unfortunately, Mr. Robertson has chosen to express the load handling capability of the regulator as a ratio of the secondary maximum kva to rated kw. In order to arrive at the more commonly used figures, it is necessary to multiply Table II, column 1 by column 2, to arrive at the permissible loading in per cent of rated kw. A suggested revision in Table II is shown in the accompanying Table A.

We believe that throughout the paper references to loading factors could be clarified by referring only to the figures shown in column 3 of the revised Table II. Also, since kva cannot be added arithmetically, but must be added vectorily, we believe that references to kva per unit throughout the paper may be somewhat confusing and might better have been omitted. It is also suggested that data should be added to Table I showing input kvar under both normal operating and open circuit conditions. This would enable interested engineers to compute regulator loadings.

Calculations based on the suggested revisions in Tables I and II reveal that the data presented by Mr. Robertson are in close agreement with those given on Westinghouse curve 433942 and on G. E. curve 251H824 at 100 per cent nominal input voltage. At 95 per cent nominal input voltage, there appears to be differences in the design of regulators offered by two manufacturers. For information on recommended loadings at 95 per cent primary voltage, the reader is referred to Westinghouse curve 349395 and to G. E. curves 251H824 and 251H825.

Mr. Robertson mentions that a five per cent allowance has been factored into the design of the regulators. This is true when Westinghouse curve 349395 or the dashed line on G. E. sheet 251H825 or the solid line on G. E. sheet 251H824 are utilized. However, it appears that the figures

in Table II are comparable to Westinghouse and G. E. curves at full input voltage and, therefore, *no* allowance has been factored into the Table II figures, as such. However, plots of the results of loading calculations for various other conditions indicate that 40-unit loading should be satisfactory for operating conditions, so long as no more than two lamps are allowed to burn out before relamping and the input voltage does not drop too low.

The kw losses in the cable are discussed and figures are presented without reference to load current. These figures are for 6.6-ampere circuits and should be so identified. At 20 amperes, as used in some circuits, the cable losses would be considerably higher.

I seriously question the statement in the paper that *most* series circuits do *not* use open-circuit protective relays. Admittedly, many series systems installed 25 to 30 years ago did not originally include open-circuit relay protection. However, many of these have been modernized to include such protection. It has been my observation that most systems being installed today include such protection.

Mr. Robertson states that these open-circuit protectives relays for 6.6-ampere circuits have been available with a 3.2-ampere rating. The very early relays were rated at 6.6 amperes and would pull in reliably at currents above 5.5 amperes. Later, the rating was changed to 3.8/6.6 amperes, indicating the minimum pull in current was 3.8 amperes and the normal operating current was 6.6 amperes. I believe that it may have been the latter to which he was referring when he mentioned a 3.2-ampere rating. Such relays might pull in at 3.2 amperes, but should not be depended upon to do so reliably. The latest design of one relay manufacturer is rated at 2.5/6.6 amperes and can be depended upon to pull reliably at 2.5 amperes.

As mentioned in the paper, it is important that the starting current and/or the hot-restrike current exceed the minimum pull in current of the series protective relay. It is to be hoped that other ballast manufacturers will furnish information on the current drawn by their units under hot-restrike conditions at various loadings, such as shown by Mr. Robertson in Fig. 5.

The data given on peak and rms open-circuit voltages provided by various transformer designs is of particular interest. It indicates that the gap in the transformer should be such that the peak oev does not exceed the values specified by ASA or the lamp manufacturer for the lamps to be used. It is important that other transformer manufacturers make available curves or data showing these characteristics of their particular design or designs for their transformers at various regulator loadings.

R. D. Churchill and E. C. Martt:* The goal of the author and others to decrease customer lighting costs is commendable, since the advantages of increasing the loading on series regulators has long been recognized. As the author points out, the introduction of the H33 lamp is a big step in this direction, since the starting voltage at low temperatures approaches the value needed for lamp stability.

The paper states that the constant current regulators discussed will deliver rated output at 95 per cent line voltage and 99.5 per cent power factor load, and that they will deliver 113 per cent of rating at nominal line voltage and unity power factor. The conversion of the first group of values to the second is not obvious from the text. Could the author explain these values in more detail?

A lamp outage of ten per cent is assumed. We doubt a street lighting system having ten per cent of its lamps out simultaneously could be tolerated. Perhaps this would be acceptable in an industrial lighting application indoors, where the illumination on the working plane comes from a great many lamps together, but there would surely be serious complaints about a street lighting system where ten per cent of the lamps were out continuously.

In Figs. 1, 3, and 5, the top curve shows an abrupt change in slope. Since, in our normal work with ballasts we do not find this type of curve, could this be caused by the touching of the moving coils of the regulator?

The author recognizes serious possible trouble with the new circuit if open-circuit voltage exceeds lamp breakdown voltage across internal lamp parts. Such a condition would result in arc-over and destruction of the lamp and socket. Some lamp manufacturers have stated that their lamps will withstand 2300 volts peak, but none as high as the 2500 volts mentioned. We would like assurance that the maximum value accepted by ASA is not exceeded. We would also like to know the methods by which the author measured these peak values.

E. B. Karns:* Mr. Robertson's paper contains much valuable information. The material which he has presented indicates that he and his associates have given considerable study and research to this problem. In general, I agree with the information contained in this paper. However, I would like to make eight specific comments, as follows:

(a) Design tests in the Cleveland Works Laboratory substantially agree with the information and data given in the paper. Our own U. A. T. design has values of impedance almost identical to those for the Jefferson Optimum gap transformer. Our own measurements of Jefferson transformers also substantiate their figures.

(b) The advantages offered by a series circuit were mentioned briefly. Can the two statements "simplified control can be used," and "maintenance costs are lower" be clarified? What is the basis for making these two statements, and do they apply strictly to the optimum air gap transformer?

(c) The statement that 95 per cent of rated input voltage to the constant current transformer need not be considered since the allowance is built into the regulator is not entirely correct. When operating a maximum load from a constant current transformer, the coils are at their minimum separation. A reduction in primary input voltage from 100 per cent to 95 per cent of rated will result in an approximate 5 per cent reduction in the maximum possible load or a reduction in the current flowing in the series circuit.

(d) Considering "cascade starting," this may be correct for a circuit with all new lamps or where random replacement is practiced. Has any information been gathered for a circuit when all lamps are near the end of life at which time they should all be harder to start?

(e) It has been implied that all of the curves were obtained from tests made with a ten-kw constant current transformer. Have similar tests ever been made using a larger transformer—*e.g.*, 30 kw? Has the transient crest starting voltage across the lamp been measured using a 30-kw constant current transformer? We measured voltages 3000 plus on minimum gap design. We can reach 2050 on our optimum gap transformer, and 1700 volts nominal.

(f) A ballast loss of 84 watts for an open-circuit condition seems high. We measure about 44 watts loss for our own transformer.

(g) With the emphasis placed on starting more mercury

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lamps, has the author conducted any tests and prepared any data showing the number of mercury lamps that may be maintained in normal operation by a constant current transformer? We are finding the quantities of lamps very much the same. At warmer temperatures, it is possible to start more mercury lamps than can be operated.

(h) Has any effort been made to operate the horizontal mercury lamps at a wattage for the lamp to produce rated lumens? We find that the author's company operates the lamp at 390 to 395 watts while a nominal 409 watts are required for rated lumen output.

J. E. LENZ:* This paper documents the behavior of the series insulating transformer for the 400-watt mercury lamp when the air gap of the transformer is varied. The principle that increased loading of the current regulator may be obtained by decreasing the air gap of the individual insulating transformer has been generally recognized by transformer manufacturers; the determination of the "optimum" gap has always been a subject for debate, due to the many conflicting considerations affected by the air gap. The author's approach to the solution of the gap problem has considerable merit, since data have been obtained by actual tests rather than by theoretical computations, which often overlook such factors as wave-shape distortion and core saturation effects.

The ceiling on maximum allowable rms and peak voltage which may be applied to mercury lamps has recently been increased by some of the lamp manufacturers. This certainly justifies taking a fresh look at transformer design to determine how far we should go in decreasing the air gap to take advantage of the permissible increase in open circuit voltage applied to the lamp at starting.

Additional factors influencing this decision, which the author has either ignored or covered inadequately, may be listed briefly as follows:

Arc stability of the mercury lamp—Excessive series-circuit loading can cause the lamp arc current to approach an "in phase" relationship with the restriking voltage available from the regulating transformer. This results in a more unstable arc, as the magnitude of the instantaneous restriking voltage is at a relatively low value when the arc current wave passes through zero. A heavily loaded circuit may pop out with as little as ten per cent dip in line voltage, whereas a moderately loaded system can stand dips as low as 20 to 25 per cent.

Decrease in lamp watts—The watts delivered to the lamp by the insulating transformer will drop off with circuit loading, even though the current regulator maintains a steady 6.6 amperes to the transformer primary. This decrease in lamp watts is caused by a distortion of the current wave shape with loading, and may amount to as much as a five per cent drop off from a lightly loaded circuit to a very heavily loaded circuit

Destructive effects of open circuit voltage peaks—Excessive peaks on the transformer open-circuit voltage wave result from a small air gap because of the heavy core saturation. Even though the lamp manufacturers have approved their lamps for use with transformers applying as much as 2150-volts peak and 450-volts rms to the lamp, there is an increased hazard of damage to lamp sockets and associated wiring with these voltages.

Telephone interference—One or more open-circuited insulating transformers on a series loop can cause wave shape distortion of the regulating transformer current, and the resulting harmonics may be coupled into adjacent telephone lines to cause interference. This effect becomes much more pronounced when open-circuit voltage peaks are excessive.

Lamp aging—As mercury lamps near the end of their useful life, they become harder to start. Although the author has considered a safety factor in his circuit loading due to reduced line voltage and open-circuited transformers, no consideration has been given to a safety factor for starting aged lamps.

A. NELSON:* We, the users of these mercury lamp transformers, are also interested in uniformity of secondary current and voltage characteristics in order to provide maximum over-all lamp efficiency and life. In comparing one type of transformer with another, it would be quite helpful to consider these additional characteristics. Curves showing secondary voltage and current, including tolerance ranges, plotted against watts load, at constant current input could be a basis for comparison.

Another consideration arises from troubles we experienced several years ago, described as pulsating current. Current fluctuation at a rate of approximately one cycle per second was noted on the primary circuit of the regulating transformer. We have never been able to fully explain the cause of the trouble, although the action was stopped by lamp replacement and/or partial substitution of mercury vapor with incandescent lamp load. If the mercury lamp transformers could have been a contributory cause, some investigation of this effect with various gap type transformers would be warranted.

W. E. MURRAY:* Other cities are experiencing the same ever-increasing rate of street light installations, and the continual uprating of lamps, as the City of Los Angeles. Emphasis on maximum constant current regulator capability is most timely.

The economics of design are mainly concerned with lowest annual cost and highest lumen-hours maintained in service.

Important elements of cost are additional circuits, increased vault space, heavy pole construction, and added energy requirements for constant current regulators derated to supply current at low power factor. The key to insulating transformer improvement described by the author is increase of power factor from 85 to 91 per cent, resulting from reduced leakage flux and leakage reactance. Changes in transformer watt loss are insignificant. Does a change of turns ratio primarily account for the higher starting voltages, or does it result entirely from saturation before secondary current flows? I would also expect higher operating voltage on all lamps while in service, and would like Mr. Robertson to comment on this. Figs. 2 and 6 show peak voltage applied to the last lamp to start, or on the socket of a faulty lamp, increased from 800 to 1800 volts. This increased sustained stress should be considered in the selection and maintenance of sockets and luminaires.

Mr. Robertson noted that voltage crest factor for the large gap design is near the sine wave value of 1.4, with all transformers open-circuited. Comparison of Fig. 1 with Figs. 2 to 6 leads to the conclusion that this crest factor is minimized by the lower current and voltage available at this loading to saturate the core.

Figs. 1 to 6, with 1.45 lamps per kw of cc regulator capacity and all transformers open-circuited, show average voltage crest factors of 1.4 for large gap, 2.5 for minimum gap, and 1.8 for optimum gap. With only one lamp remaining out of service, average voltage crest factors are 2.2 for

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**Dept. of Water and Power, City of Los Angeles, Calif.

large gap, 5.3 for minimum gap, and 4.0 for optimum gap. Open-circuit secondary voltages of high harmonic content, requiring magnetic flux and primary voltage components of the same frequencies, evidently exist at all transformers supplying lamps out of service. The electrical characteristics of the series circuit are fortunately such as to restrict these effects primarily, although not entirely,[1] to the open-circuited transformer. Apparently the optimum gap transformer is required to operate under a condition of considerable saturation at this time. I would like information on the winding temperature rise during sustained open-circuit operation after lamp failure. I would also appreciate Mr. Robertson's comments on his oscillographic studies of series loop current, and of voltage and current wave shapes delivered to operating lamps by the optimum gap transformers, with up to ten per cent of other transformers open-circuited. Specifically, I am concerned with the crest factor of current supplied to operating lamps which bears on lamp maintenance[2] and on telephone interference.

Mr. Robertson's interesting discussion of cascade starting describes a unique form of self-regulating lamp-starting system. The constant-current series circuit provides the current-limiting function required by negative resistance load characteristic of mercury vapor lamps. Shift of voltage to hard-starting lamps is one bonus of the insulating transformer system compared to a straight series system. The allowance of ten per cent of lamps out of service is quite generous and should provide for minimum standards of maintenance.

1. Knowlton, A. E.: "Standard Handbook for Electrical Engineers," 8th Edition, Par. 6-147 (1949).
2. Martt, E. C. and Smith, R. J.: "Measurement of Mercury Lamp Current Crest Factor And Its Effect on Lumen Maintenance," ILLUMINATING ENGINEERING, Vol. LIII, No. 12, pp. 630-640 (December, 1958).

W. A. ZANDER:* Mr. Robertson has cited a paper of mine as his sole reference, therefore, since I am in the user category, in effect, it seems natural that my remarks should follow an operational line and the examination necessary to use properly the transformer which he has described.

Before getting involved however, I would like to advise those who may be interested in reviewing the paper to which Mr. Robertson has referred. It was originally presented before the Transmission and Distribution Committee of the Edison Electric Institute at the February, 1956 meeting in Philadelphia, and titled: "A New Approach to Loading Series Street Lighting Circuits for Vapor Type Lights." As such it was recorded in the minutes of that meeting. It subsequently appeared in *Electric Light and Power* as noted.

I am happy to comment on Mr. Robertson's paper because, in my opinion, he has presented a worthwhile and long overdue improvement of the transformer component for series-circuit operation of mercury vapor lamps. This should prove to be of great value to those users who are obliged to adapt new mercury vapor lamp installations to series circuits which are already in existence.

One point that Mr. Robertson does not seem to have made is that if the 400-watt mercury lamp plus transformer has a power factor of 0.91 or better, the permissible lamp loading on the regulator is the same, for all practicable purposes, as would be the case with 10,000 lumen group replacement filament lamps. This circumstance presumes that the regulator to be used will have an impedance no greater than 55 to 56 per cent. This is a very happy situation if one has been operating with 10,000-lumen units and wishes to only double the light level. Only fixtures and lamps need be changed.

*Detroit Edison Co., Detroit, Mich.

This apparent coincidence is what we were hoping we might be able to achieve when we established that the theory of cascade starting of mercury vapor lamps was sound. Our initial work was done in the latter part of 1955, and using the transformers then available we found that both in theory and practice we could safely load a 30-kw 50 per cent impedance constant current transformer with 50 400-watt mercury vapor lamps. This, however, left us no margin for failed lamps or higher regulator impedance. Since we could have both conditions, we backed the loading figure down to 45 units per 30-kw transformer, and have been working very successfully this way ever since. The improved transformer will make it possible for us to equal or exceed our original objective. We will probably not go beyond 50 units per 30-kw regulator because some of the older design insulating transformers could get into the circuit. In the event we could depend on having only new design coils, a well-patrolled area such as a super-highway, a constant current transformer with a 48 per cent to 50 per cent impedance, and a supply voltage not more than four per cent low, we could plan on 55 units/30 kw cc transformer.

Except under storm or freak circumstances, we have rarely had more than one failed lamp at a time on a circuit. It must be that outages with this type of lamp are so infrequent that when one does fail it is immediately conspicuous and so reported. On the basis of our experience, then, I would not subscribe to Mr. Robertson's pessimistic allowances for 10 per cent non-operating lamps. Instead, loading figures of 52 to 55 units per 30-kw regulator seem to be definitely practical, even with an old (4000 to 6000 hours use) H1 lamp.

Unless one is faced with an abnormally low and prolonged supply voltage condition, say 40 per cent of rated, it is not necessary to provide extra margin for regulation (excluding allowance for failed lamps). It is questionable if any moving coil unit can mechanically keep pace with a quick dip in voltage which becomes insufficient to maintain the lamp arc. Regulation in this case is first due to the dynamic characteristic of the circuit which includes all the regulator reactance. Therefore, impedance as load is essentially as effective as leakage reactance, so load up the circuit. This keeps the lamp voltage under better control when supply is restored after, say, a ten cycle interruption, and eliminates the need for time delay equipment.

In connection with improving the efficiency of loading constant current transformers insofar as mercury vapor lamps are concerned, another benefit accrues, particularly when a transformer load is exclusively mercury lamps. The series circuit is very apt to have a potentially damaging transient current during the half cycle at the time it is energized. The magnitude of this transient is a function of the impedance of the regulator supply source, the actual time of circuit closure during that half cycle, the impedance of the regulator, and to a lesser degree, the magnitude of the connected series-circuit load. On an insulating transformer, whose secondary is open circuited, this transient will appear as an abnormally high voltage. It follows that more load units will reduce the magnitude of this transient at each lamp, which is definitely to be desired. As a matter of caution avoid testing the control action of a series circuit by repeated cycling of same, especially if the lamps have come up to temperature. This can be disastrous for both mercury and filament lamps.

There is one point in this paper with which I wish to take issue. This is not peculiar to this author but is a carry-over from similar ratings applied to filament lamps, and concerns the emphasis placed on unit lamp loadings in terms of lamps per kw of regulator rating, or, as others have

done, kw of regulator capacity per lamp. This point is a technicality, but important in the philosophy of designing series circuits for vapor lamp loading.

In order to achieve *maximum* circuit efficiency with mercury lamps on series circuits, new or old, they must be designed with full recognition of all circuit factors because the over-all circuit power factor is very significant. This means that regulator impedance must be known as well as its minimum dependable supply voltage. If the voltage is always favorable, the regulator can be up-rated accordingly. Then there is the circuit conductor, *e.g.* armored cable can have a power factor of 0.83 to 0.85 in addition to its a-c resistance being greater than its d-c resistance. It also means that the total circuit load characteristic must also be known. The normal loading is watts or volt amperes at a specific power factor when mercury lamps are properly operating. The abnormal condition is a lesser circuit power factor when insulating transformers have open-circuited secondaries which occur when any lamps have failed. In the case of mixed circuit loading it also occurs with filament lamp transformers if film cutouts are not used.

This open-circuited condition has largely been ignored in the case of filament lamp load calculations because at worst all that could happen is that lamps would be less bright because of reduced current. In the case of mercury lamps, however, shifts in circuit power factor, whatever the cause, can result in circuit instability so far as the lamps are concerned. Therefore in designing series circuits for mercury lamps, particularly in the case of mixed loading, one should not think in terms of how much regulator capacity will be allowed for each operating lamp, but rather what is the minimum over-all circuit load power factor that can be reasonably maintained. This will be governed by both the characteristics of the constant current transformer and the user's practice with regard to lamp replacement. Such an approach will result in maximum efficiency of circuit loading in the light of each user's circumstances and will avoid wasting regulator capacity because of unwarranted overconservatism.

In conclusion I would like to say that operation of mercury vapor lamps by loading the series regulator in accordance with its capability has proven to be wholly satisfactory. The dependence on random starting characteristics of lamps and the consequent cascade action in starting is reliable, and the entire starting action is ordinarily complete in less than a second for large circuits. The transformer that has been described should present no lamp starting difficulties because available voltages for starting under maximum regulator loading conditions are equal to or greater than those supplied by transformers with much larger leakage reactances.

In the matter of the inherent deficiency of series circuit turn-on transients, neither the large or optimum gap transformers are likely to exhibit any marked superiority because the transient time is such as to rule out much influence by the transformer core.

I am glad to know that one manufacturer has given serious consideration to improving the circumstances whereby mercury lamps may be operated on series circuits. No doubt others will follow suit. There appears to be little room for circuit power factor improvement except in the way of lamp improvement. This is one place where circuit capacitors cannot be used to advantage.

M. E. ROBERTSON:* I want to thank Messrs. Churchill, Martt, Lenz, Nelson, Blackford, Karns, Murray, and Zander for their interest in my paper, their kind remarks, and their constructive discussion. There were two comments made by several of the discussers and these will be covered first.

*Author.

TABLE I (Revised)—Input Characteristics of Large Gap, Minimum Gap and Optimum Gap Insulating Transformers Under Open Circuit and Operating Conditions at 6.6 Amperes.

Lamp Operating	Large Gap	Minimum Gap	Optimum Gap
Input kva	.510	.462	.472
Input kw	.433	.430	.430
Input kvar	.269	.167	.195
Power Factor	85	93	91
Open Circuit			
Input kva	1.19	1.48	1.32
Input kw	.08	.084	.084
Input kvar	1.19	1.48	1.32
Power Factor	6.7	5.7	6.3

The reference in the paper to a 3.2-ampere open-circuit protective relay is incorrect and should have been 3.8 amperes. This correction rules out the possibility of using 1.45 lamps per kilowatt of regulator capacity for the large gap transformer. The use of a 3.8-ampere protective relay limits the loading to about 1.25 large gap, 1.4 minimum gap or 1.45 optimum gap transformers per kilowatt of regulator capacity. Table IV (which accompanies this discussion) shows the allowable number of lamps which can be used if a 3.8-ampere protective relay is the limiting factor. Compare Table IV with Table III of the paper.

The statement was made in the paper that the regulator was compensated for by 95 per cent line voltage so additional allowance was not necessary. This is not correct. Table II is for 100 per cent line voltage but allows for ten per cent of the lamps being out at one time. This is pessimistic enough to take care of a 95 per cent line voltage condition.

To illustrate this, Table V was prepared for this discussion, which shows allowable lamps per regulator with 95 per cent line voltage, a maximum of one lamp per regulator out at any one time, and circuit loss allowance. Compare Table V with Table III and you will note some increase in the allowable number of lamps on the larger regulators with the greatest gain on the optimum gap unit. Note that a 2.5-ampere open-circuit protective relay can be used at these loadings but not a 3.8-ampere relay.

In discussion of Mr. Blackford's comments, I want to thank him for the suggested corrections, the kind words, and the confirmation of some of my findings.

It is surprising to learn that cascade starting can occur on a straight series system and welcome to have confirmation of —20-degree starting of H1 lamps at 190 volts. Mr. Blackford's correction of available starting voltage rather

TABLE II (Revised)—Relation of Maximum Regulator Capacity at Rated Secondary Current to Secondary Load Power Factor (Mathematically Derived Curves).[1] 50 Per Cent Minimum Impedance Regulator. 100 Per Cent Line Voltage.

Load Power Factor	Maximum Capacity In Per Cent of Rated kw	
	kva	kw
65	76	49.4
70	77.5	54.3
75	79	59.2
80	82	65.6
85	86	73
90	91	81.9
95	98	93

than open-circuit voltage in the discussion of cascade starting is accepted and his comments on safe luminaire design are appreciated.

Mr. Blackford's suggestion that regulator derating be expressed in kw as a percentage of rated kw is a good one. This is shown here in a revised Table II. His suggestion for including kvar in Table I is also well-received and a revised Table I showing kvar is shown here.

We seem to disagree upon the usage of open-circuit protective relays; however with the new 2.5-ampere unit the disagreement becomes less important.

Mr. Blackford deserves much credit for his helpful and astute comments.

Messrs. Martt's and Churchill's comments are also well-received and appreciated. The regulator rating method was taken from a currently available manufacturer's catalog and I suggest that a regulator manufacturer be consulted for a full explanation.

The use of ten per cent lamp outages is probably too pessimistic. My Table V, shown in this discussion, illustrates more optimistic lamp maintenance of one lamp per regulator out at one time. The abrupt change in slope of regulator current in Figs. 1, 3, and 5 represents the point at which the regulator coils come together and the regulator ceases to regulate. The optimum gap transformer as shown in Figs. 5 and 6 does comply with proposed ASA specifications for maximum peak and rms voltages. The peak voltage was measured with a resistance voltage multiplier with the voltage being applied directly on the plates of an oscilloscope. This method was determined to be sufficiently accurate for the application.

Mr. Karns had some interesting comments, especially those which supported and verified my findings.

My statement regarding "simplified control" and "lower maintenance" applied generally to series circuits using isolating transformers since time delay relays and film cutouts are not required.

Mr. Karns' question (c) has already been answered. Question (d) is an interesting one and presumably if a regulator were fully loaded with no safety factor, then aging lamps might be a problem. In practice at least, some lamps would have been replaced before all of the lamps became old. These replacement lamps would start the cascading. Further, at least one lamp manufacturer and one utility believe that lamps do not get harder to start with age. In any event, it is felt that sufficient margin has been allowed in available starting voltages to start old lamps.

His question (e) refers to operation on larger than ten-kilowatt regulators. We have made tests on a 30-kilowatt with only one transformer as a load. The open circuit and peak values went up slightly; however, the optimum gap transformer values were still well under proposed ASA specifications and apparently under the Westinghouse values.

Mr. Karns' question (f) leaves me without an answer. Our current production averages 72-watts input to an optimum gap transformer with 6.6 amperes in its primary and one unit on a ten-kilowatt regulator. Perhaps Mr. Karns checks this in a different manner.

TABLE IV—Constant Current Regulator Loading For 50 Per Cent Impedance Regulators For 400-Watt H1 or H33 Mercury Lamps with Insulating Transformers. Minimum Circuit Current Limited to 3.8 Amperes By an Open Circuit Protective Relay.

	Number of Lamps				
Regulator Rating in kw	10	15	20	25	30
Large Gap (Factor .78)	13	19	25	32	38
Optimum Gap (Factor .69)	14	22	29	36	43

TABLE V—Constant Current Regulator Loading for 6.6 Amperes 50 Per Cent Impedance Regulators For 400-Watt H1 or H33 Lamps. Allowance Has Been Made for 95 Per Cent Line Voltage, One Lamp Outage Per Regulator, and 100 Feet of #6 Cable Per Lamp (.0019 kw and .001 kvar Per Lamp). 2.5-Ampere Open Circuit Protective Relay Can Be Used.

	Number of Lamps				
Regulator Rating kw	10	15	20	25	30
Large Gap Transformer	14	22	29	37	44
Optimum Gap Transformer	16	24	33	42	50

In answer to question (g), yes, more lamps can be started than can be operated. We find that the major limiting factor is a 3.8-ampere open-circuit protective relay and the next limiting factor is loading of the regulator.

Question (h). We design to meet the NEMA specifications of minus five plus ten per cent lamp watts. This allows for operating a horizontal lamp at its rated watts, not rated lumen ouput. At least one lamp manufacturer recommends operation at rated watts rather than rated lumens. The two units which Mr. Karns checked were on the low side of nominal but well within NEMA specifications. I think if he checked our current production, he would find lamp watts up appreciably.

I thank Mr. Lenz for his comments regarding my approach to the air gap problem. I would like to comment on the "additional factors" in the order presented.

(a) I cannot agree with this conclusion on lamp stability since if it were true it would also apply to multiple circuits which it obviously does not.

(b) If the current regulator maintained a steady 6.6 amperes to the insulating transformer primary, we observed no drop off of wattage with circuit loading due to distortion of current wave shape or any other cause as long as the limitations of the circuitry were observed. The recommendations made in this paper take into account actual operating conditions and warn the user to consider maximum loading in view of system maintenance. Within these limitations we expect no wattage "drop off."

(c) If associated circuitry will not stand proposed ASA voltages, it is time to either change ASA standards or design better components. Existing equipment is designed for sine wave test voltages whose peaks far exceed 2150 volts; therefore there should be no cause for worry except in sub-standard equipment.

(d) Field experience does not bear out the theoretical approach to telephone interference. Other discussers of this paper have stated that ten per cent lamp outages were excessive and that in actual practice systems would be maintained at a higher level. This does not leave much room for open-circuited transformers causing regulator current distortion.

(e) The question of lamp aging was covered under the discussion directed at Mr. Karns.

I thank Mr. Nelson for his comments. The additional data asked for would indeed be helpful to a user. Most of it, however, can be taken for granted since NEMA and ASA specifications and lamp manufacturers' tolerances determine these factors.

The problem of pulsating current possibly was due to the regulator being loaded just to the point where the coils were touching. Apparently, insufficient safety factors had been allowed and perhaps too many very old lamps were on

the system. A slight dip in the line voltage would cause a reduction of series current. The lamps would then be operating at a lower wattage and would start to cool down. This would reduce the load on the regulator and allow the series current to increase and the lamps to warm up again. The regulator coils would go back together and so on causing a pulsating or hunting condition.

I want to thank Mr. Murray for commenting especially since he had obviously made a concentrated study of my paper.

The change in turns ratio as well as the higher saturation point account for the higher open-circuit voltage. The operating voltage of the lamp is not higher because of the turns ratio, since other factors must be considered. The insulating transformer must be designed to operate the lamp at rated wattage and current and as a result the lamp voltage is correct. Changes in core construction, leakage flux, core losses and exciting current, as well as turns ratio make this possible.

Mr. Murray is correct in pointing out the differences in open-circuit crest factor. An open-circuited insulation transformer will affect the regulator to a slight degree but only on the wave shape of its terminal voltage. The series current wave shape will not be affected as long as the regulator coils are not touching and the regulator is delivering 6.6 amperes. There will be no effect on the insulating transformers or lamps which remain in service since their operation depends entirely upon the series current value and wave shape and not on the wave shape of the regulator terminal voltage. The operating lamp current wave shape is very good and approaches a sine wave; therefore the lumen maintenance should be very good.

An insulating transformer will run hotter open circuited than when operating a lamp. This condition has been recognized and the transformers are designed to operate at a safe temperature even when under open circuit.

I want to thank Mr. Zander for his comments as well as for allowing me to use his paper as a reference. Mr. Zander's comments indicate that he not only agrees with my approach to the problem but he states that I have not gone far enough; *i.e.*, my approach is too conservative. He has been using 45 large gap units on a 30-kilowatt regulator and is proposing to standardize on 50 optimum gap units while considering 55 for specific installations. My Table V suggests 50 units.

I agree with Mr. Zander in that each system should be carefully considered for maximum loading and that all circuit factors should be included in the calculation. My paper gives the transformer parameters for various conditions and allows the application engineer to properly consider the transformer along with the other circuit factors for maximum regulator loading. The lamps per kilowatt of regulator rating factor is too indefinite for precise loading.

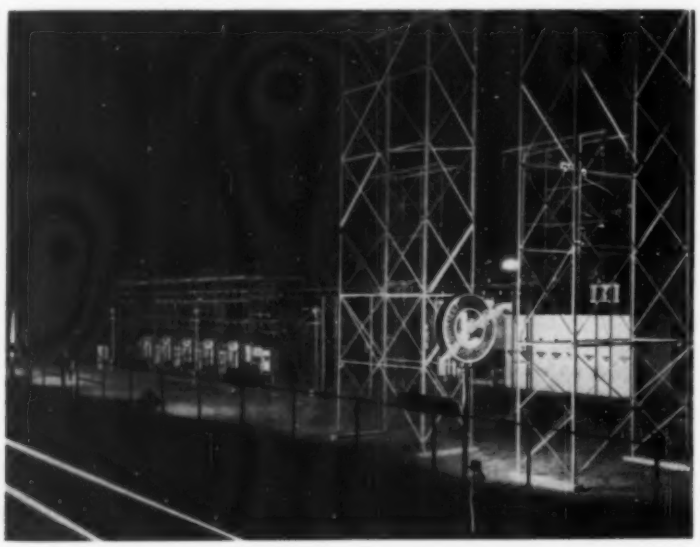
Mr. Zander's other comments are pertinent and appropriate. I want to again thank him for his original help and supporting discussion.

Fluorescent Substation Lighting

Considerable attention from passing motorists (and the attendant publicity to the power company) has resulted from recent applications of fluorescent lighting to substations. The installation shown here (Louisiana Power and Light Co.) uses a fluorescent floodlighting unit designed especially for such jobs. The unit is made to be mounted on the fence around the perimeter of the area, directing light into the superstructures. This is an effective departure from conventional substation installations where incandescent units are mounted directly on the superstructures and light directed up and down.

In this installation, luminaires equipped with standard high output fluorescent lamps are mounted on 30-foot centers six feet above ground on the top rail of the fence. Measured illumination between luminaires, at mounting height, is between four and five footcandles.

Photo and data are courtesy of Louis C. Odry, 1958-59 Editorial Representative, Milwaukee Section.



CALIBRATION

and Re-calibration of Photoelectric Meters to Correct for the Spectral Characteristics of the Measured Light

By LEO LEVI

Because the spectral response of a photoelectric device differs, in general, from that of the standard observer, it is impossible for one calibration of a photoelectric meter in photometric units to be accurate for various light sources of different spectral characteristics. Correction factors are derived, with which a reading must be multiplied, if the measured light has a spectral distribution different from that used in the original calibration. Also given is a relatively simple method for calibrating any photoelectric meter if a source of known intensity and spectral distribution is available.

BECAUSE of the wide-spread use of photoelectric devices for the measurement of illumination and brightness, it should be of general interest to investigate the applicability of absolute readings of luminous flux with such devices. In some cases, these instruments are calibrated in arbitrary units, permitting only relative readings. In other cases, the meters are calibrated directly in footcandles or other photometric units, ostensibly making it possible to determine illumination or brightness in absolute terms.

Unfortunately, the superiority of the latter calibration is to a certain extent illusory. The calibration must be based on an assumed spectral distribution of the light source and when the instrument is then used on a light source with a different spectral distribution, the calibration will no longer be valid, except if the spectral response of the photoelectric device follows accurately that of the standard observer. Since this latter condition is very difficult to achieve, even with optical filters,[1] the calibration of the footcandle meter or brightness meter will frequently be useless. This is particularly true with the increased use of fluorescent and arc lamps. Due to the line-spectrum inherent in these light sources, a minor discrepancy of the spectral characteristics may result in a major error in the measurement.

In view of the above difficulties, it might be of interest to users of electric photometers to have available a method for converting their relative brightness readings into absolute photometric units and to be able to compute correction factors to compensate for the discrepancy between the response of the photoelectric device and that of the standard observer.

Such correction factors are frequently mentioned in the literature[2,3,4,5] and may be obtained empirically by using the calibrating source and the source to be measured in conjunction with a visual photometer. The alternative, a numerical computation of the correction factor, does not seem to be available in the literature. A report of the Committee On Photoelectric Portable Photometers of the Illuminating Engineering Society[6] derives some of the basic relationships but does not give a calibrating procedure nor a complete formulation of the correction factor to be applied to a previously calibrated "footcandle meter."

It is therefore felt that, despite its relative simplicity, a presentation of the required results might be useful to a large number of users of photoelectric photometers, especially to those who are not too familiar with photometric principles.

Spectral Calibration and Correction

The spectral calibration and correction factors involve integrals of the products of the following functions of the optical wavelength (λ): the relative spectral response of the standard observer (k), the relative spectral response of the photosensitive device (p), the relative spectral characteristic of the calibration light source (c), and the relative spectral characteristic of the light source to be measured (m). It is assumed that the above functions, k,p,c and m are all known; they may be chosen to any linear scale. Their magnitudes will be designated by K_k, K_p, K_c and K_m, respectively,

AUTHOR: Consulting Optical Engineer and Physicist, New York, N.Y.

only for the purpose of deriving the desired factors. These magnitudes need not be known.

In addition to the above relative spectral characteristics, only the intensity of the calibrating source must be known in order to calibrate any photoelectric device for any given light source.

Let us assume that a known amount of luminous flux (F_c) from the calibrating light source produces a meter reading (M_c). An unknown amount of flux (F_o) from the light source to be measured produces a meter reading (M_o). We may then clearly write

$$M_c = K_p\ K_c \quad \int p\ (\lambda)\ c\ (\lambda)\ d\lambda \tag{1}$$

$$F_c = K_k\ K_c \quad \int k\ (\lambda)\ c\ (\lambda)\ d\lambda \tag{2}$$

$$M_o = K_p\ K_m \quad \int p\ (\lambda)\ m\ (\lambda)\ d\lambda \tag{3}$$

$$F_o = K_k\ K_m \quad \int k\ (\lambda)\ m\ (\lambda)\ d\lambda, \tag{4}$$

where all the values of the left hand members will be known, with the exception of the last one. It follows from the above equations that

$$F_o = \frac{M_o\ F_c}{M_c} \quad \frac{[\int k\ m\ d\lambda]\ [\int p\ c\ d\lambda]}{[\int p\ m\ d\lambda]\ [\int k\ c\ d\lambda]}, \tag{5}$$

where all the factors of the right hand member are known.

NOTE: The integrals are probably most readily determined by choosing a series of wavelengths $\lambda_1, \lambda_2 \ldots\ldots \lambda_N$, such that successive wavelengths differ by a conveniently small amount $\triangle\lambda$. The integrals can then be approximated by summations as follows:

$$\int a\ b\ d\lambda \doteq \triangle\lambda \sum_{n=1}^{N} a_n\ b_n. \tag{6}$$

If the meter is already calibrated in photometric units, it is, of course, not necessary for the user to use his own calibrating light source. In that event, $M_c = F_c$ in equation 5 and the spectral correction factor to be applied to the reading M_o will be simply:

$$\frac{[\int k\ m\ d\lambda]\ [\int p\ c\ d\lambda]}{[\int p\ m\ d\lambda]\ [\int k\ c\ d\lambda]} \tag{7}$$

The values of the latter integrals in the numerator and denominator could be supplied by the manufacturer together with a tabulation of p. The user can then compute the former integrals for the particular light source he is measuring.

Radiant Flux Measurements

In some cases it may be of interest to measure radiant flux (in watts) rather than luminous flux (in lumens). In that case the above expressions (5) and (7) may still be used, merely setting $k = 1$, $F_o = R_o$, $F_c = R_c$, where R_o is the amount of radiant flux to be measured and R_c is the radiant flux of the calibrating source.

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Library's Luminous Ceiling

Luminous ceiling, 40 by 60 feet, with 40-watt rapid-start fluorescent lamps, mounted above ⅜-inch cell plastic louver panels, results in 50 fc of low brightness, diffuse illumination at Midland Public Library, Midland, Texas. Lamps are mounted in tandem in eight-foot two-lamp fluorescent strip, on two-foot centers, in the plenum. Air diffusers have been integrated into ceiling in a pleasing architectural pattern. Photo and data courtesy of Edwin F. Guth Co., St. Louis, Mo.

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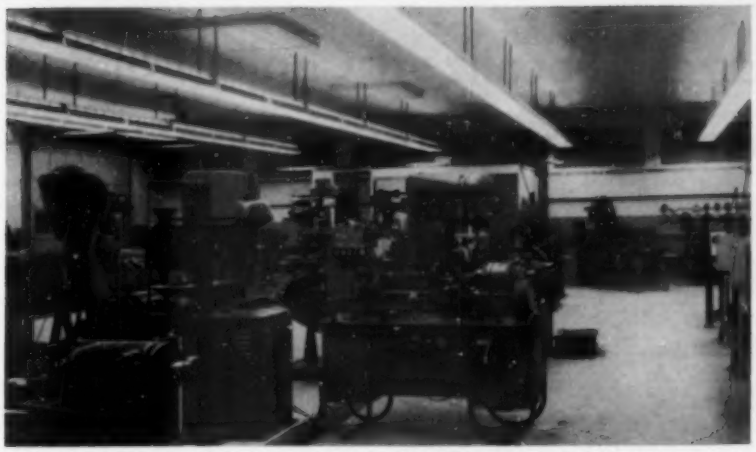

INSTALLATION AT B & F TOOL MACHINE CO., COLLEGEVILLE, PA.

Lighting a Machine Shop

LIGHTING OBJECTIVE: To provide general illumination in a machine shop for medium bench and machine work.

GENERAL INFORMATION: This machine shop, which has a ceiling height of 12 feet, measures 48 feet by 65 feet. One side wall contains roll-up flexible overhead doors for truck access. Colors and reflectances in the shop are:

ceiling	white plaster	80% RF
walls	white	75% RF
dado	gray	33% RF
floor	gray	36% RF
machines	gray	18% RF

INSTALLATION: Thirty-six Wheeler-Fullerton catalog No. D8585-DIF-RS industrial type luminaires with a 15 per cent upward component are suspended 24 inches below the ceiling and are arranged in continuous rows 8 feet on centers. Units have been omitted where there are overhead obstructions such as at the overhead door locations. Each luminaire is 8 feet long and is equipped with two 96-inch T-12 cool white, rapid-start fluorescent lamps operated at 800 ma.

After 300 hours operation the average illumination level was approximately 100 footcandles. Brightnesses were:

ceiling	16 fL	floor	29 fL
walls	37 fL	machines, horizontal	18 fL
dado	16 fL		

Lighting designed by Charles W. McQuiston, Philadelphia Electric Company, Philadelphia, Pa. Installed by the owner.

Lighting data submitted by Charles W. McQuiston and George T. Anderson, Jr., Philadelphia Electric Company, Philadelphia, Pa. as an illustration of good lighting practice and to aid in the design of similar installations.

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Evaluation of

Methods for Localized Cooling of Fluorescent Lamps in Outdoor Luminaires

By M. E. KECK

LIGHT OUTPUT and luminous efficacy of a fluorescent lamp are affected by internal factors such as dimensions, electrodes, type of gas and filling pressure, and arc watts per square inch of phosphor area; by external factors such as ambient temperature, auxiliary electrical equipment characteristics and previous history of operation, such as hours in operation and hours per start.

This discussion is not concerned with internal design factors nor previous history factors and care was exercised to eliminate these from affecting the data. This paper is concerned with the external factor—ambient tempertaure and its effect on light output and power consumption.

Lamp Operation Under Varying Ambient Temperature Conditions

Light output and luminous efficacy of a fluorescent lamp vary as a function of ambient temperature since the ambient temperature immediately around the lamp normally determines the temperature of the lamp bulb wall, the minimum bulb wall temperature is one of the factors which controls the mercury vapor pressure. At lower than optimum bulb wall temperatures, more of the mercury condenses and at the resulting lower pressures, the optimum energy wave length (2537 Angstroms) is produced less efficiently. At higher than optimum bulb wall temperatures, more of the energy radiated in this line is absorbed by the mercury vapor and does not reach the phosphor for conversion to visible light.

In this rather complex way, the light emitted is affected by ambient temperature. This information is usually published by lamp manufacturers in a form similar to that in Fig. 1, which shows the variations in light output with ambient temperature for lamps designed to be operated at 430 ma, 1000 ma, and 1500 ma respectively. Such curves are usually based on the following concepts:

(1) Rated lamp current at all ambient temperatures.

(2) Lamps mounted singly and in such a manner as not to impede normal air flow around the lamp envelopes.

(3) Lamps mounted in such a large enclosure (room) that their own heat does not measurably affect the ambient temperature in that enclosure.

From Fig. 1 it would appear that all three lamps are well suited for operation in ambient temperatures of 50F to 90F and that some, particularly the 1500-ma type, are not suitable in cold ambient temperatures. This, of course, would be true if the lamps were used in service under exactly the same conditions as those listed above. In most outdoor luminaires, the lamps are enclosed to protect them and the reflectors from the elements, dirt, and insects. Once the conditions listed above are violated, the relationship of light output (and brighteness) to the ambient temperature outside the enclosing luminaire changes drastically (Fig. 2).

All references to lamps enclosed in a luminaire, in this paper, refer to a two-lamp fluorescent street

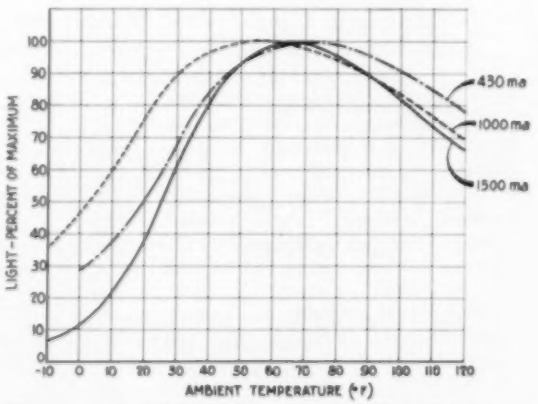

Figure 1. Variations in light output with ambient temperature for T12 fluorescent lamps of varying design current loading. Lamps operating in free air.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHOR: Lighting Division, Westinghouse Electric Corp., Cleveland, Ohio. Accepted by the Papers Committee as a Transaction of the IES.

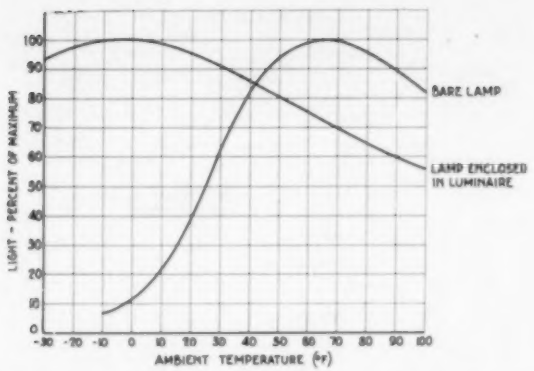

Figure 2. Variation in light output with ambient temperature for 1500-ma T12 fluorescent lamps when operated in free air and when operated in a luminaire of the type shown in Fig. 3 with no lamp cooling utilized.

lighting luminaire utilizing a Fiberglas outer housing, specular aluminum inner reflector and a transparent acrylic enclosure of prismatic configuration. The luminaire is shown in Fig. 3 and is normally equipped with two 72-inch T-12 1500-ma extra-high-output fluorescent lamps. As the data of Fig. 2 indicate, the ambient temperature outside the luminaire at which maximum light output occurs now shifts to zero degrees, and when the outside air temperature is 70F, the light output is 70 per cent of that at zero.

If the IES Recommended Procedure for Photometric Testing is followed, the penalty for this reduced lamp output at the standard testing temperature of 77F (25C) appears in the form of reduced luminaire effiicency. While this is right and proper, it may not be generally recognized and often is not readily discernible to the engineer using such a curve. Table I indicates variations in luminaire efficiency using the same luminaire with lamps at various current loadings. Luminaire efficiency varies from 41 to 64 per cent depending on the lamps and conditions used in the test, and only in the last instance does it indicate the true efficiency of the optical design since only in the last case is the lamp producing the same light output inside the luminaire as it does on the calibration rack.

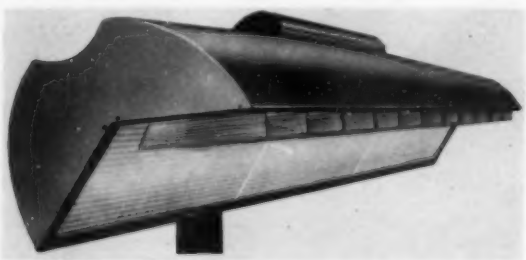

Figure 3. The type of outdoor enclosed luminaire used for all test work reported. Luminaire consists of a Fiberglas housing, specular reflector, plastic door and accommodates two 1500-ma T-12 72-inch fluorescent lamps.

It has been shown by Waymouth[1] that the light output of a lamp can be made relatively independent of ambient temperatures above that required for optimum light output by cooling a small area of the lamp. This is effective since the mercury vapor gas pressure is controlled by the coolest spot on the bulb envelope. The time required to reach stabilization is a function of the size of this area.

If it is assumed that a particular enclosed fluorescent luminaire produces an internal ambient temperature and bulb-wall temperature in excess of that required for optimum lamp output, it is possible to improve its performance by the following means:

(1) Circulate air within the luminaire generally, thus increasing the transfer of heat and achieving a reduced cool spot temperature on the lamp, the location of which may be random.

(2) Direct a stream of cool air against a particular portion of the lamp, and achieve a small cool spot in a predetermined loctaion on the lamp.

(3) Produce a cool spot on the lamp by conduction. This would normally require direct contact to the bulb wall by a conducting object.

(4) Produce a cool spot on the lamp by means of a refrigeration system.

The four approaches above are general in nature and literally hundreds of individual schemes, depending on luminaire design and other factors, may be conceived as variations on the above.

General Air Circulation Vs. Directed Air Flow

The advantages of general air circulation as a method of improving performance include (a) simple addition of a fan or blower can be made to existing designs; (b) the general ambient inside the luminaire is lowered, thus improving temperatures on ballasts, sockets, lamp phosphors, and plastic parts; (c) system provides some benefit regardless of location of design cool spot on the lamp.

TABLE I — Luminaire Efficiency with Various Lamps. Ambient Outside Luminaire—77F

Luminaire Efficiency	Lamps
41%	1500 ma—no localized cooling
51%	1000 ma—no localized cooling
56%	430 ma—no localized cooling
64% (Optical Efficiency)	1500 ma—with cool spot at 100F

The disadvantages for general air circulation include (a) maximum improvement in performance is not likely to be secured; (b) larger size fans and motors are required to achieve comparable results in performance; (c) luminaire construction may be such as to make general circulation of air difficult.

The advantages of directed localized cooling are as follows: (a) air from the coolest location within the luminaire can be directed against the lamp; (b) luminaire construction can be designed to provide a flow path to achieve maximum radiation of heat; (c) smaller sized blower and motor may be utilized to achieve desired performance; (d) the directed air flow can strike the lamp at its design cool spot.

Disadvantages of directed air flow include (a) the most effective system for lamps with varying design cool spots located in different areas cannot be achieved; (b) luminaire design may require extensive modification to achieve a good flow path.

Air Cooling vs. Conduction and Refrigeration

Conduction and refrigeration methods would normally require physical contact between the lamp bulb wall and the cool device. Good thermal contact is difficult to achieve and for experimental purposes thermal conducting greases were used at the contact points. The practical problem of lamp replacement, tolerance of lamps and maintenance of the thermal junction are not easily solved. All systemes discussed are heat transfer systems and work best under conditions where the lamp requires the least cooling and have their least efficiency under conditions where the lamp needs maximum cooling. It becomes difficult to vary the amount of cooling depending on the atmospheric ambient temperature with a conducting system, and somewhat difficult with refrigeration techniques.

Conducting and refrigeration methods provide for little or no reduction in overall ambient temperature inside the luminaire and in the work done by the author some evidence has been found that permanent phosphor deterioration occurs rapidly if lamps are operated at excessively high ambient temperatures. Exploration of this will be continued as the data at present does not warrant drawing definite conclusions.

It is quite possible that future lamp development may remove the entire problem or make more practical a thermal contact for better results with this type cooling.

Performance Results with Various Localized Cooling Means

The luminaire chosen for experimental work is shown in Fig. 3 and consists of a Fiberglas housing

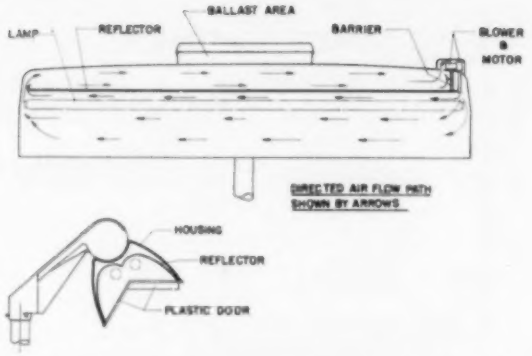

Figure 4. Location of blower and air flow path to provide directed localized cooling of the lamp and recirculate air for maximum radiation of heat.

with partial ribs supporting a snap-in specular reflector. The ballast is mounted in an external enclosure. This construction does not lend itself to the use of a fan for general air circulation since it could only be located within the optical system. It does, however, lend itself to creating a controlled flow path of air and the extra-high-output lamp, which is designed with the cool spot at the base of the lamp, is ideal for localized cooling at the end of the lamp. The location of the blower and the flow path are shown in Fig. 4. No outside air was introduced into the luminaire in the experimental work reported; merely controlled circulation through the luminaire was utilized.

The luminaire construction also lends itself well to experimental work with a thermo-electric element with its "cold" end attached to a short probe contacting the lamp and its "hot" end connected by means of cooper rods to small radiators outside the luminaire. This construction is shown in Fig. 5. When a proper d-c source is applied to the

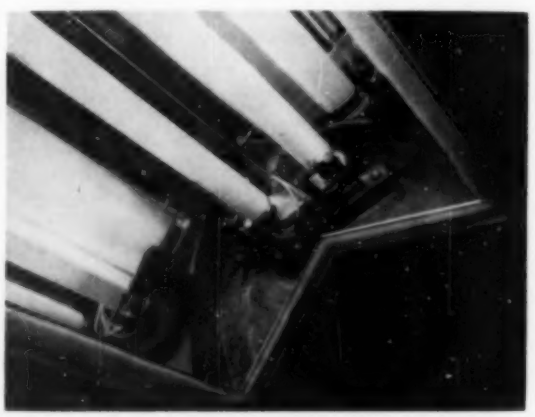

Figure 5. View of thermo-electric refrigeration element to provide small cool spot on end of lamp envelope.

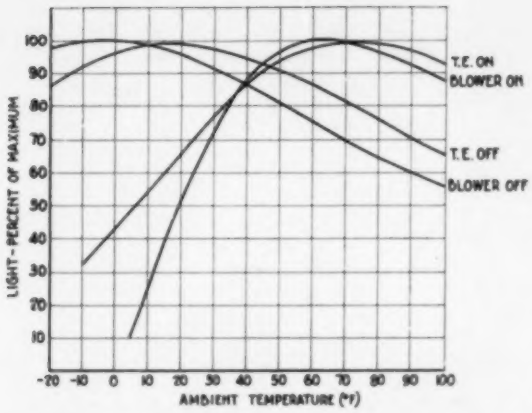

Figure 6. Relative light output of luminaire with both directed air cooling and thermo-electric refrigeration cooling energized and de-energized.

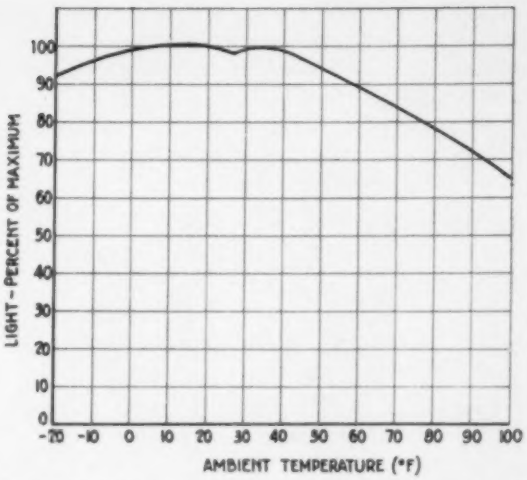

Figure 7. Relative light output of luminaire equipped with modified directed air cooling and thermostate control to switch blower motor on and off.

thermo-electric element, a small area of the lamp can be cooled quite adequately.

The shift in maximum light output point with the blower on and off and with the thermo-electric junction energized and de-energized is shown in Fig. 6. It is obvious that with either method maximum light output can be forced to occur at relatively high ambient temperatures outside the luminaire and that, as the outside ambient temperature falls, it becomes necessary to de-energize the cooling means to maintain maximum light output. It is evident that the thermo-electric elements, even when de-energized, provided sufficient cooling by conduction to shift the de-energized curve measurably higher than the curve for lamps operating with blower de-energized.

Table II indicates the cool spot temperature, average bulb-wall temperature, relative light output at 77F (ambient outside luminaire) and ballast input power under the three important conditions. It should be pointed out that the air flow path of the localized cooling reduces average bulb-wall temperature significantly. It should also be noted that excessive cool-spot temperature in addition to reducing light output, also rather drastically reduces ballast input power.

TABLE II — Lamp Characteristics for Various Cooling Means. Ambient Outside Luminaire—77F

Cooling Method	Cool Spot Temperature Degrees F	Avg. Bulb Wall Temperature Degrees F	Relative Light Output	Ballast Input Power Watts
None	136	155	66%	263
Refrigerated Spot	100	189	100%	345
Directed Air Flow	106	134	97%	330

For practical reasons, development work was continued on the basis of a directed air flow system. In order to eliminate the drop in light output at the cross-over points on Fig. 6 and to make the construction more practical, baffles rather than ducts were used to direct the blower output to the end of each lamp. A thermostat located to sense housing temperature was used to control the blower motor. The relationship of luminaire output to outside ambient temperature for such a production luminaire is shown in Fig. 7. This results in a somewhat lower output at 77F than in the experimental luminaire which is felt proper since all test data was taken with approximately one-mile-per hour air circulation and outdoor air currents usually are greater. This results in a shifting of the entire curve towards the higher temperature end by improving convection cooling of the housing.

Conclusions

It is the author's opinion that the following general conclusions can be drawn:

(1) Fluorescent lamps, in particular those operating at 1500 ma, produce extremely poor light output when operated in an enclosed luminaire with outside ambient temperature above 50F.

(2) Personnel evaluating outdoor fluorescent luminaires must be certain that the conditions of test are correctly and adequately known since the IES Recommended Photometric Test Procedures reflects reduced lamp output in terms of reduced luminaire efficiency.

(3) Maintenance of a cool spot on the lamp by any of several means appreciably increases light output at elevated ambient temperatures.

(4) The selection of a particular method of cooling the lamp, or a spot thereon, is a function of the desired results and practical consideration in each design situation.

(5) It appears that conducting or refrigeration techniques require lamp and lampholder design changes to permit practical usage.

Acknowledgments

The author wishes to express his appreciation to G. A. Horton for photometric measurements, and C. H. Loch for many hours spent in preparing and testing experimental models and procedures used as the basis of this paper.

Reference

1. Waymouth, J. F., Bitter, Francis, and Lowry, E. F.: "Factors To Be Considered in Design of High Output Fluorescent Lamps," ILLUMINATING ENGINEERING, Vol. LII, No. 5, page 257 (May 1957).

DISCUSSION

JOHN J. HARDY:* Natural ventilation is a method of cooling fluorescent lamps not discussed by Mr. Keck. The twelve-lamp fluorescent street lighting luminaires, consisting of a row of six 72T12/CW/RS lamps on each side, which the Indianapolis Power & Light Co. has in use, have vents in the bottom of the plastic cover and two rows of vents at the side of the aluminum housing below the top of the fixtures on each side. These vents run the entire length of the fixtures.

Soon after the installation in November, 1955, of these luminaires, we experienced excess lamp outages and it was determined that these outages were due to the basing cement baking and cracking the glass on the lamps. There was also a phosphor deterioration. All of this was due to high temperature spots in the fixtures.

Of the total burnouts only one per cent occurred in the bottom pair of lamps, while the pair of lamps next to the top had the highest burnout, 29 per cent of the total.

Installation of a circulating fan near the center of the fixture above the lamps, causing a vertical movement of air in addition to the natural ventilation, reduced hot spots in the fixture at one point as much as 50 degrees Centigrade, providing excellent lamp performance and increased light output over normal temperature range. Operation of the fans has been satisfactory with no maintenance problems encountered since their installation three years ago.

Primary disadvantages of natural ventilation are: (a) excess dirt on lamps and glassware inside the fixtures and (b) physical obstructions restricting the free flow of air.

H. A. VAN DUZEN, JR.:** This excellent paper deals with a subject that will most likely become quite prominent in the near future; namely, controlling light output by spot cooling of fluorescent lamps. By the process of controlled spot cooling it is practical to maintain near optimum light output of fluorescent luminaires through a large ambient temperature range.

The luminaire used by the author in his evaluation is apparently relatively cool operating as compared with many luminaires commonly used. This was a two-lamp luminaire and I notice that the light output of the combination not using lamp cooling is approximately 65 per cent of optimum at 77F. This can be compared with a more heavily loaded four-lamp type fluorescent luminaire which operates at higher temperature rise resulting in light output as low as 53 per cent of optimum at 77F (still air). If the lamps in a heavily loaded fluorescent luminaire are maintained at near optimum light output by spot cooling, then it can be seen that the room temperature light output of such a luminaire will be almost double. By proper control of the cooling scheme, the light output of such a luminaire can be made to be almost constant through a very wide range of ambient temperatures. Two very significant benefits would be gained in such a luminaire:

(a) The useful light output of such a luminaire will be much greater; thus, fewer luminaires will be required to accomplish a given lighting job. The economic savings, considering the reduction in the number of mounting structures, justifies the cost of equipping the luminaires with controlled spot cooling devices.

(b) Application of such luminaires will be simplified and be more precise because the light output is not dependent on ambient temperature and wind.

We have been conducting experiments along the same general line and I am happy to find many areas of agreement with the author's findings, although there are a few areas where we are at variance. I will discuss some of our findings as they refer to the author's paper.

Size and Location of Cool Spot

The author states that the time required for the lamp to reach stabilization is a function of the size of the cool spot area. Our findings tend to indicate that the time required for the lamp to stabilize is primarily a function of the time required for the mercury vapor to migrate from various locations within the lamp to the cool spot. The location of the cool spot will presumably have a larger effect on the time to reach stabilization than the size of that spot. I have noticed that if a lamp has previously been operated with natural cool spots, located at a distance from a new artificial cool spot, then there is a very considerable time required for the mercury vapor to migrate to the new cool spot area. Times as long as four to six hours are typical for this.

Before the lamp has stabilized, the lamp bulb wall brightness is highest near the cool spot and this condition remains fairly stable until all the excess mercury finally drifts to and condenses out at the cool spot. When this occurs, the brightness becomes uniform very rapidly, the total light output, arc volts, and the watts input to the lamp all increase. These changes occur within a matter of minutes and are quite spectacular to watch.

When only one cool spot per lamp is used, then the stabilization time is minimum if that spot is located at the center of the lamp, as the mercury ions then have the least distance to migrate.

An artificial cool spot performs satisfactorily at any point on the lamp except near the hot cathodes. We have found that this cool spot can be as small as .15 per cent of the surface area of the lamp and still perform satisfactorily.

The amount of heat energy required to maintain the proper cool spot temperature is a function of the size of the cool spot. The energy pumped consists of radiant heat from the arc that is intercepted by the cool spot area plus heat of condensation of the mercury. There will also be a certain amount of heat picked up from the higher temperature air in the lamp chamber. Intercepted radiant heat from the

*Indianapolis Power & Light Co., Indianapolis, Ind.
**Line Materials Industries, South Milwaukee, Wis.

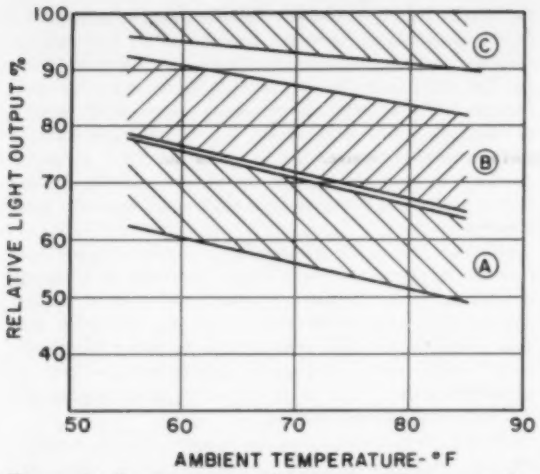

Figure A. Comparative performance of fluorescent luminaire with and without lamp cooling. Measured outdoor operation. *Luminaire A*—Reference luminaire without lamp cooling. *Luminaire B*—General circulation of internal air. *Luminaire C*—Spot cooling of lamps with thermo-electric heat pumps.

are is dependent on the size and location of the cool spot. The heat of condensation is constant for a given temperature condition and appears to be somewhat less than six watts for 1.5 ampere 72-inch lamps.

The author describes four ways to achieve artificial cooling. I will discuss these in order.

1. General Air Circulation

This can provide some gain of light output; however, most fluorescent luminaires operate at such high internal ambient air temperature that the lamps cannot be cooled to their optimum temperature and very little light output gain is possible. In many cases, the increase in light obtained by general air circulation is less than half of that possible by use of effective spot cooling.

2. Directed Air Stream

This scheme can provide optimum cooling. The amount of air required is not great; however, the air within a luminaire is generally at a much higher temperature than the approximately 100F required for spot cooling. Outside air can be used for cooling. However, this air must be well-filtered; otherwise sufficient dirt will enter the luminaire by this means to seriously contaminate the optical surfaces and reduce light output. The internal air may be used if it is cooled by means of a heat exchanger. Disadvantages of this system are the problems of adequately filtering the outside air or obtaining an adequate heat exchanger. It is difficult to control the cooling rate to maintain the proper spot temperature as the thermal lag of the lamp bulb wall is so low that a simple off-on control for the blower would be operating every several seconds. If the on-off control is not fast enough, the light output swings through a rather wide range, sufficient to result in a noticeable flicker.

3. Cooling by Conduction

The author tends to dismiss the feasibility of cooling by conduction. It is true that it can be difficult to control the cooling rate by this method. Many luminaires are so constructed that the distances from the lamp to the outer housing are too great to allow practical conduction of heat from a lamp cool spot to the outside by a metal conducting bridge. There are other methods of conducting heat over a distance than by the use of a metallic bridge, however, and there is room for considerable ingenuity in this field. One example would be the use of a liquid-filled system. The author mentions the difficulty of obtaining good thermal contact with the lamp bulb wall. He stated that he has used thermally conducting greases experimentally. I see no objection to such use in practice.

4. Refrigeration System

Modern developments of the thermo-electric heat pump have made this a very practical method for achieving spot cooling. The principle employed in thermo-electric heat pumps is the Peltier effect in which direct current flowing through a junction of two dissimilar metals gives rise to the absorption of heat in one junction and the liberation of heat in the other. The concept has been known for many years. However, the efficiency was rather low until the recent developments of new semi-conducting materials. In our work with the thermo-electric heat pump we mount the device fully within the luminaire as it is often not feasible to expose the hot junctions directly to the outside air due to the large distance between the lamps and the outer wall of the luminaire. I note that the author has found that there is excessive lamp cooling by conduction at low ambient temperatures due to exposing the hot junctions to the outside air and thus the cold temperature performance of such a luminaire is degraded.

We use a thermo-electric heat pump equipped with cooling fins on the hot junctions for cooling by internal luminaire air. The cold junctions contact the lamps. Control is by means of a thermostat attached to one of the cold junctions which maintains the cold junction at the proper temperature by means of cycling the d-c power source that provides the operating power for the thermo-electric heat pumps.

The decrease in light output of fluorescent lamps operated with a cool spot temperature much higher or lower

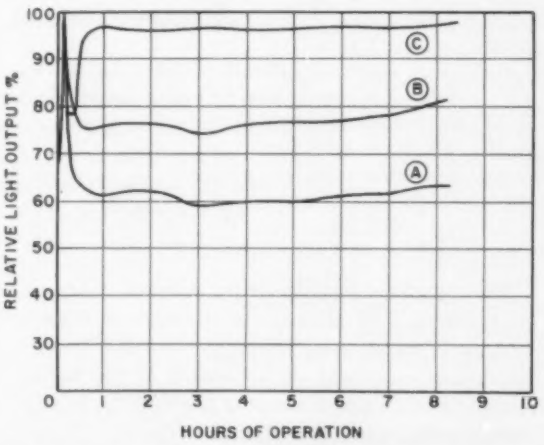

Figure B. Comparative performance of fluorescent luminaires with and without lamp cooling. Measured outdoor performance night of June 27, 1959. Ambient temperature 81F to 87F; wind velocity 7 to 8 mph. *Luminaire A*—Reference luminaire without lamp cooling. *Luminaire B*—General circulation of internal air. *Luminaire C*—Spot cooling of lamps with thermo-electric heat pump.

than optimum is due to the decrease in efficiency of light generation and a very significant reduction in wattage consumed by the lamp. The wattage variation is considerable and in a high ambient temperature condition the lamps may be consuming only two-thirds to three-quarters of their rated watts. Cooling of a spot on the lamp to optimum temperature brings this wattage up to rated.

The function of controlling the temperature of a cool spot on the lamp bulb wall can be compared to grid control of a vacuum tube. A very small amount of thermal energy applied to the lamp bulb wall can change the energy consumed by the lamp by a much greater factor and will change the light output by an even greater amount.

Artificial spot cooling may make it possible to develop higher loaded lamps. Presently, one major limitation to increasing current loading on fluorescent lamps is a difficulty in maintaining satisfactory natural cooling. Artificial cooling may remove this limitation.

M. E. KECK:* The constructive comments of both Mr. Hardy and Mr. Van Dusen, Jr. are appreciated and serve to bring out important points in regard to this subject. Mr. Hardy rightly indicated that the problem is more extensive than merely providing a cool spot on the lamp of optimum temperature; it must also include means of insuring that other points on the lamp do not exceed other temperature limit criteria. In the basic paper, it is pointed out that the lumen maintenance will be adversely affected if the phosphor temperature is excessive. Thus, it is not practical to limit the cooling to one small area and completely neglect the other temperature limitations of the lamp construction.

Mr. Van Dusen, Jr. apparently disagrees with my conclusions in regard to the practical problem of utilizing, conducting, or refrigeration techniques in which a "cold" element must contact the lamp. It is my contention that three practical problems exist relative to such a technique:

(a) Maintenance of a good thermal junction between glass and metal. Use of a thermally conducting grease *will* be a maintenance problem.

(b) The cold element must be so mounted as to properly contact both T-12 and T-17 lamps since such lamps are electrically interchangeable in the 1500-ma type.

(c) Additional cooling must be provided to counteract the other temperature problems, as outlined by Mr. Hardy and myself.

*Author.

Errata—General Secretary's Report

An oversight resulted in the omission of a report of the 1958-59 activities of the Industrial Lighting Committee from the General Secretary's Report, published in the December, 1959 issue of ILLUMINATING ENGINEERING *(page 787). The following is a summary of the committee's work, reported by L. G. Parks, Chairman.*

The committee consists of ten members including the chairman. In addition, there are seven subcommittees. Five of these subcommittees are, at present, actively working on a revision of the Recommended Practice of Industrial Lighting in five different manufacturing industries. One subcommittee is working on a revision of the American Standard Practice for Industrial Lighting; the remaining subcommittee is inactive at present. The six industry subcommittees cover aircraft manufacturing, clothing, graphic arts, outdoor productive areas, electronics and woodworking.

The committee's activity during the past year consisted primarily of initiating revision of the American Standard Practice for Industrial Lighting. A joint meeting was held with the American Standard Association A-11 Sectional Committee on Industrial Lighting. At this meeting the Industrial Lighting Committee outlined the planned revision together with the background developments which necessitate the proposed revision. A subcommittee, under the chairmanship of D. J. O'Neill, was formed to write this revision.

In addition, the work of the Clothing Industry Subcommittee was completed and is awaiting formal approval by the main committee.

Practical Guide to Colorimetry

Prepared by the Subcommittee on Practical Guide to Colorimetry of Light Sources of the Committee on Testing Procedures for Illumination Characteristics of the Illuminating Engineering Society

FOREWORD

The color of light sources and the color rendering of the light sources are becoming increasingly important in designing today's luminous environments. This Guide, which has been under development for over two years, has been prepared to aid in that direction.

SUBCOMMITTEE ON PRACTICAL GUIDE TO COLORIMETRY

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W. H. Houston — A. W. Weeks

COMMITTEE ON TESTING PROCEDURES FOR ILLUMINATION CHARACTERISTICS

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T. H. Leister — S. W. Wilson

P. L. Young

1. Scope

(a) In evaluating the color performance of lamps, there are two important factors to be considered; namely, color rendition (non-improved-color mercury lamps cause the human complexion to appear greenish), and color appearance (a daylight fluorescent lamp appears blue by comparison with an incandescent lamp). Color rendition of a light source is the degree to which the perceived colors of objects illuminated by the source conform to those of the same objects illuminated by a reference source, for specified viewing conditions. The usual conditions are that the observer has normal color vision, and is similarly adapted to the environment illuminated by each source in turn. There is, at present, no generally accepted method of evaluating this property numerically; hence, it will not be discussed in this guide. A subcommittee of the IES Light Sources Committee is presently working on this problem.

(b) Color appearance has to do with apparent color of a light source to an observer. Color appearance can be evaluated numerically; and is the subject of this guide. At present, the Barnes Colorimeter is in very common use, and is the principle instrument described in this guide.

2. Color Temperature

(a) Incandescent filament lamps give off light as a result of the temperature at which the filament is operated. The color appearance of such a lamp is a function of the temperature of the filament. This can be illustrated by considering a piece of metal heated through increased temperatures, giving off light ranging from dull red at lower temperatures, to blue-white as it becomes hotter. The color of light escaping from a small hole in a heated enclosure or blackbody radiator depends only on the temperature of the enclosure, and for light sources approximating such radiators, the color of the light is best described by giving the absolute temperature of the corresponding blackbody emitter. This temperature, called color temperature, usually is expressed in degrees Kelvin.

(b) Researches have shown that in the case of incandescent filament lamps not only the color appearance but the distribution of energy in the spectrum is determined by the color temperature at which the filament is operated. Thus, this number serves fully to describe the color and the energy distribution of the incandescent source.

(c) Electric discharge lamps and lamps depending on activated phosphors as their light source are not dependent on temperature for their radiation characteristics. Other means then must be found in order to express their color appearance numerically. See Section 4.

3. Colorimetry

(a) It is well-known that if an observer with normal vision is to match a spot of variable colored light to an adjacent spot of fixed color, it will be necessary to adjust three independent color controls. A match obtained by adjustment of less than three components is pure accident.

(b) This illustrates that normal color vision is tri-dimensional and points to a basic law known as Grassman's Law which may be stated as follows: "If a light composed of known amounts of three components (called primaries) is equivalent in color to an unknown light, the three known components may be used as a specification for the unknown light." These amounts are called tristimulus values of the color.

4. The Evaluation of Color in Terms of Color Vision

(a) The curve showing the brightness response of the human eye to light of various wavelengths is the familiar spectral luminous efficiency curve. This shows the relative eye sensitivity to light at wavelengths within the visible range. The discrimination of color is,

Approved by the Council of the Illuminating Engineering Society, September, 1959. A Transaction of the IES.

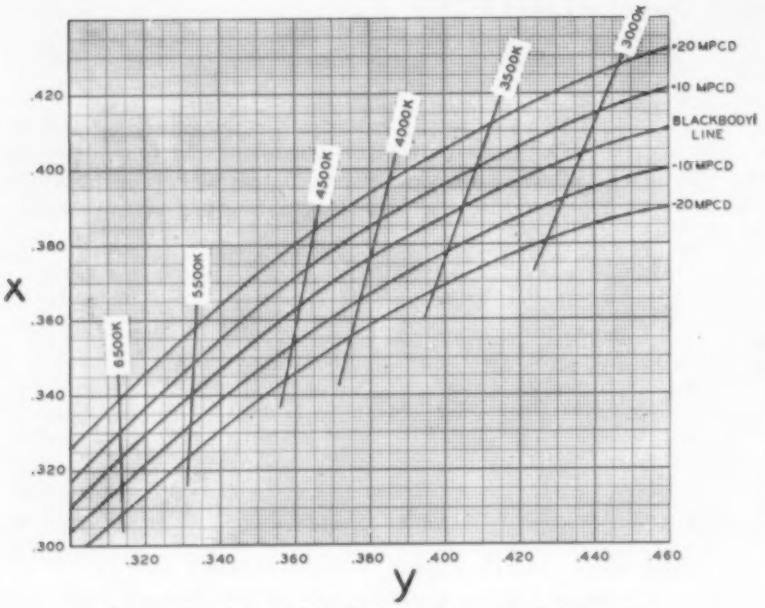

Figure 1. Section of 1931 C.I.E. Chromaticity Diagram.

however, far more complex; and to translate measurements of flux at the various wavelengths emitted from a light source to a specification of its color, as an observer sees it, requires a system of weighting the relative effects of the spectra on the eye. These weighting functions for what is termed a "standard observer" (the average of some two hundred subjects) were adopted by the International Commission on Illumination (C.I.E.) in 1931. These data are available for the necessary three *tristimulus value functions* in the form of tables and curves. Weighting the measured spectrum of a light source by these functions produces what are known as "tristimulus values X, Y, and Z." The function for Y was chosen so that the Y value is proportional to the photometric brightness (luminance) of the color being specified. Color is usually designated by chromaticity co-ordinates (x, y, and z) which can be computed from the "tristimulus values" as fractions of their total.

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

It should be noted that $x + y + z = 1$; hence, chromaticity can be defined by the use of any two of these chromaticity co-ordinates. It is customary to use x and y.

(b) The section of the lamp being observed must be clean, since any surface deposit may be color selective. Color measurements usually are taken after the lamp has been burned 100 hours. Most types of lamps do not change color appreciably during life, but some types do.

5. Color Temperature Designation and Chromaticity Coordinates

The calculated x and y values of a light source provide, in certain cases, a means of obtaining an abbreviated method of color designation in terms of color temperature and deviation from the blackbody locus. The "blackbody line," or Planckian locus, frequently shown on the chromaticity diagram, is the line at which blackbody radiation, depending entirely on the temperature of the source, is plotted; hence, any x and y values which plot directly on this line can be designated by temperature in degrees Kelvin. If the plot of x and y for a light source falls close to the blackbody line, a correlated color temperature may be designated together with an additional number to show the departure from blackbody temperature. This additional number is in units of the minimum perceptible color difference (MPCD)[1] observable by the human eye under the most sensitive viewing conditions. This MPCD figure is preceded by a plus (+) if the shift is toward the green side of the locus, and a minus (−) if toward the purple side. These data may be calculated or read from an expanded chart. Fig. 1 shows such a chart. Such evaluation is strictly valid only for colors close to the blackbody line. The color temperature of a source which is far removed from the blackbody line is almost meaningless and very difficult to estimate. Limits for acceptance of a color source can be described in terms of MacAdam ellipses. The method of calculating these ellipses was described in the *Journal of the Optical Society of America*.[2]

6. Spectroradiometry

(a) The fundamental method of evaluating the color of a light source is to determine its spectral radiance,[3] then weight these data according to the accepted C.I.E. tristimulus functions. The first part, accurate evaluation of spectral radiance, is more easily described than accomplished. The problem is similar to that of spectrophotometry of reflecting or transmitting materials, but there is one important difference; namely, simple ratios of reflected-to-incident or transmitted-to-incident light cannot be utilized as the measured parameter. Spectroradiometry requires that both the spectral transmittance of the monochromator, and the spectral sensitivity of the detector be known, or that the spectral radiance of an unknown source be determined relative to the spectral radiance of a known source, such as a blackbody radiator (or lamp) operating at a known color temperature.

(b) The problems of spectrophotometry and spectroradiometry are similar since in each case the ideal of maximum spectral purity and the practical consideration of providing sufficient energy at the exit slit must be balanced, so that the detecting system will have adequate sensitivity. Operation with wider slits than desired may be necessary in order to satisfy the energy requirements of the detector for minimum acceptable sensitivity. In spectrophotometry, the source intensity

may be increased in order to obtain more energy at the detector for a given slit width or to permit reduction of slits without reducing the sensitivity of the detector. In spectroradiometry, however, measurements are usually required on a source of a given brightness (luminance). In some cases, spectroradiometry of very low brightness sources is desired. Because the photoreceptor must be permitted a time integral of radiant flux in order to maintain sensitivity, strong sources can be measured rapidly, but weak sources will require a longer time for measurement.

(c) Spectroradiometry has never been standardized to the extent of spectrophotometry because of the wide variety of sizes, shapes, and intensities of sources for which data may be required. Neither has any instrument design so far met with universal acceptance. Most spectroradiometers in use today have been designed and built to meet particular research or production requirements. Published information on the design or construction of particular instruments is included in the annotated bibliography, together with the material pertaining to the analysis of the results of spectral radiance data, particularly the problem of evaluating the color contribution of line spectra in the presence of continuous spectra.

7. Barnes Photoelectric Colorimeter

(a) The Barnes type colorimeter,[4] commonly used in color measurement of fluorescent lamps, produces electrical responses to light of various wavelengths which are proportional to the theoretical values of X, Y, and Z. It usually consists of an assembly of cells, filters, and diaphragms shielded by a box-like enclosure. The filtered cells and diaphragms are mounted in the enclosure, approximately twenty inches from its viewing aperture. The aperture should be such that the cells view the full diameter of the fluorescent lamp under test, and about ten inches of its center section. The distance from the plane of the aperture to the center line of the lamp is of the order of two inches. The Y and Z components can be measured with one filtered cell each, but the X component requires three such cells in parallel to measure the theoretical X value (see Fig. 2). Diaphragms in front of the cells permit adjustment of the ratio of their responses. Cell output for the X, Y, and Z values can be read on a microammeter or a current balance.

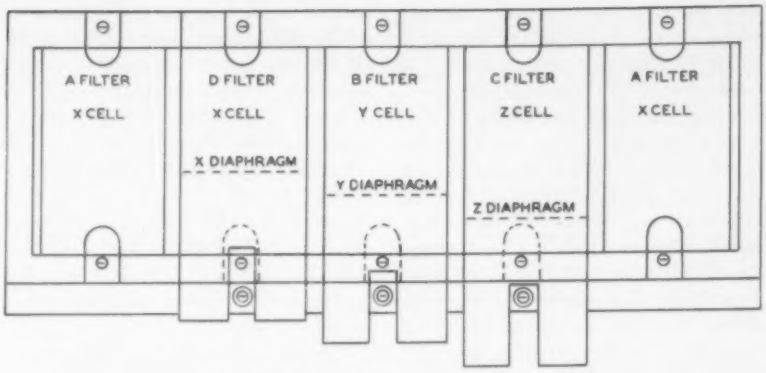

Figure 2. Barnes type colorimeter.

(b) Extraneous light should be excluded from the cells, and can be readily detected by turning off the lamp under test and checking for zero cell output. The ballast used for operating the lamp under test may be an ASA Reference Ballast, or a commercial single-lamp ballast selected to be within close limits of the ASA rating for the type lamp under test.

7.1—*Adjustment*—(a) The exposed areas on the various cells of a colorimeter required to make the instrument approximately direct-reading cannot be calculated with the required precision since the spectral sensitivities of cell-filter combinations ordinarily are determined at only eight wavelengths. After removing the top of the colorimeter box, it is easy to adjust the diaphragms step by step until the correct chromaticity co-ordinates are obtained on a particular color standard lamp. The color standard lamp is warmed up at least 12 minutes, and the line voltage is held constant throughout the adjustments. A d-c milliammeter is inserted between the terminals provided for this purpose on the current balance, or in series with the auxiliary battery. The instrument current is held to an arbitrary fixed value. Thus, adjustments are made in terms of arbitrary instrument readings rather than adjusting the current in the main circuit of the current balance so that the dials indicate chromaticity co-ordinates directly during the adjustment.

(b) The diaphragm on the cell with the "*D*" filter must be adjusted first. For this purpose, a 20-watt or 40-watt daylight fluorescent lamp is used. It should be located at the standard distance from the cells, and lined up so that its axis intersects the axis of the colorimeter. Spectral emittance data on a lamp of this type show that the current from the cell with the "*D*" filter should be 18½ per cent of the total current from the two cells with "A" filters. To accomplish this adjustment, the "*D*" filter is covered with a piece of black paper, the selector switch of the current balance set on the X position (measuring the "*A*" filtered cells) and the reading at the balance position recorded. Then the black paper is removed, and the diaphragm on the "*D*" filtered cell adjusted until a current reading 1.185 multiplied by the reading with the "*A*" filter above is obtained.

(c) For the other adjustments, it is not necessary to use a color standard daylight fluorescent lamp. One may substitute any white color standard fluorescent lamp. The lamp is given an adequate warm-up and an X reading is taken. Then, if x, y, and z are the chromaticity co-ordinates of the source, the diaphragm under the "*B*" filter is adjusted to make the Y reading equal (y/x) multiplied by the X reading. Similarly, the diaphragm under the "*C*" filter is adjusted to make the "*Z*" reading equal (z/x) multiplied by the X reading.

(d) If it is impossible to obtain enough current from one of the cells to fulfill the condition outlined above, even with the diaphragm removed from the cell, a diaphragm should be placed under one of the "*A*" filters. In this

case, the adjustment should be made in terms of the reading on the cell which needs no diaphragm. This reading is taken first. If, for example, it is the Z reading, the diaphragm under the "B" filter is adjusted to make the Y reading equal (y/z) multiplied by the Z reading. Next, black paper is put over the cell which is under the "D" filter. Then the diaphragm which has been placed under one of the "A" filters is adjusted to make the X reading equal .81 multiplied by (x/z) multiplied by the Z reading. Now the black paper is removed and the diaphragm under the "D" filter is adjusted to make the X reading equal (x/z) multiplied by the Z reading.

(c) To make the chromaticity co-ordinate corrections for both daylight and white lamps small, rather than having them zero for a particular white lamp, preliminary adjustments of the diaphragm should be made on a lamp of one chromaticity, and the readings taken on one of the other chromaticity. The effects of further adjustments of the exposed areas may be computed in advance by adjusting the corresponding chromaticity co-ordinates in proportion, then dividing the three adjusted values by their sum in order that the corrected co-ordinates add up to 1.000. Thus, one may find the optimum adjustment by computation. In making these final adjustments, one should be careful not to move the diaphragm under the "D" filter since it determines the ratio of the X response for wavelengths less than 505 millimicrons to that for wavelengths greater than 505 millimicrons.

7.2—*General Suggestions*— (a) Line voltage should be maintained within very close limits while taking readings of X, Y, and Z. Any change in voltage between readings destroys the relationship, thus giving a false result. Actually, if a current balance is used so that zero resistance is placed across the cells and the X, Y, and Z units connected in parallel, the total cell output is a measure of the light output of the lamp. Since these are photometric measurements, all of the precautions such as power supply characteristics, ambient temperature, lamp stability, drafts, etc., should be observed.

(b) If a colorimeter could be adjusted to read absolute values of X, Y, and Z, no corrections of the readings would be necessary, but such accurate adjustment is not practical. Fluorescent lamps tentatively standardized for x and y values based on visual assignments by the National Bureau of Standards are available. These standardized lamps should be read on the colorimeter. The difference between the assigned values of x and y and the colorimeter reading should be applied to the readings of the unknown lamps as corrections.

(c) All cell, bridge, and switch connections should be kept very clean and tight, and the filters and cell windows free from dirt.

7.3—*Limitations of Barnes Colorimeter*—Because of the fact that the photocell-filter combinations used in the colorimeter only approximate the response functions X, Y, and Z for the standard observer, and because of practical limits in adjusting the colorimeter according to the procedure outlined above, there are certain basic limitations in the application of the colorimeter. Color standards are used in order to establish corrections for each restricted chromaticity range, *e.g.*, fluorescent lamps in some of the various colors are available as standards for this purpose. However, a word of caution is necessary since it is possible to obtain fluorescent lamps having the same color appearance but appreciably different spectral energy distributions. Corrections for the colorimeter obtained with a color standard are applicable only to other lamps of the same, or approximately the same, spectral energy distribution. A knowledge of this characteristic is, therefore, necessary before proceeding with measurements of this type. Unless such precautions are taken, lamps which look alike may measure appreciably different, or lamps which measure alike may be found to appear different in color.

8. Color Matching by Visual Judgment

(a) The purpose of evaluating the color appearance of light sources is usually to keep products (possibly fluorescent lamps) within limits so that they look alike. It seems reasonable to ask the opinion of qualified observers and abide by their findings. This procedure can be used if the best methods and the limitations of the methods are fully recognized.

(b) The ability of observers to discriminate between small color differences is by no means equal even if color blind, or partially color blind, persons are excluded. Color matching experience is very helpful, but that experience should be accumulated upon a basis of known color differences. There should be some assurance that the color judgment is correct, particularly in the observer's learning period. The "Color Aptitude Test," prepared by the Inter-Society Color Council, seems to offer considerable promise in selecting individuals with innate ability to distinguish small color differences. This test involves matching color chips and rating the results. The American Optical color test is useful in excluding color-defective observers.

(c) The technique of matching light sources by eye deserves some consideration. Lamps to be compared should be adjacent to each other, and neither the standard nor sample should be the end lamp; that is, there should be lamps at each side of those being judged. These outside lamps should be similar in color to those being judged. All lamps involved should have about the same brightness. The background may affect the observer's judgment because of the color of the reflected light. It should be nonselective and of matte finish. The center portion of the lamp is usually used for color judgment. The observer should inspect the standard and the unknown from at least two directions, and at grazing angles.

(d) The ability of the observer not only to detect small color differences but to determine the difference of hue, may be important. For example, if the sample is somewhat bluer than the standard, the addition of red to the sample may be indicated, and a skilled observer can frequently judge the percentage of red that should be added.

(e) Observations, combined with colorimeter data, can be very useful if the limitations of both are well understood. It is perfectly possible for two light sources of different spectral compositions to have exactly the same appearance to the normal observer. Such stimuli are called metamers and are said to form a metameric pair. Such a pair may be a satisfactory match even though the measured data may not appear to be similar.

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LIGHTING NEWS

Division of Midwestern Region To be Proposed to Council

At the local activities meeting of the Midwestern Region of IES, at the Bismarck Hotel in Chicago, December 4, 1959, a unanimous vote was recorded on the motion to request Council to approve the division of the present Midwestern Region into two groups.

Several plans for the geographic division of the Region have been submitted by a Task Committee, appointed in November 1957, but essentially, the recommendations involve Upper and Lower Midwest Regions, with the two new groups to serve alternately as hosts to the annual regional conference.

A request by the Iowa Section to split into two groups was also approved by the regional activities meeting. This proposal will be submitted for future Council consideration.

A total of 33 officers and committee chairmen from eight of the Region's twelve Sections and Chapters attended the meeting.

VIP's participating in Midwestern Region local activities meeting in Chicago's Bismarck Hotel were IES Managing Director, A. D. Hinckley (left) and Second Vice President, James R. Chambers (second from left). Shown here with Messrs. Hinckley and Chambers are, left to right: Midwestern Regional Vice President, Brooks Chassaing and four members of the host Chicago Section—Benjamin F. Avery, Chairman; Eldon H. Witte, Secretary, Ernest H. Gallet, Vice Chairman and Joseph A. Schneller, former IES Director.

NEMA Reports Organization of Insulating Materials Division

The first of eight industry groups to be formed within the National Electrical Manufacturers Association, in accordance with the newly-approved NEMA organizational plan, is the Insulating Materials Division. Members of the Division's Board of Directors represent Sections composed of manufacturers of electrical glass insulation, laminated products, manufacturered electrical mica, varnished fabric and paper, varnished tubing and vulcanized fiber.

E. R. Perry, president of National Vulcanized Fibre Co., was elected Chairman of the Division's Board of Directors. In being elected to this post, Mr. Perry also becomes a vice-president of NEMA and a member of the Officers Committee. D. J. O'Conor, Jr., Formica Corp. and R. L. Westbee, Irvington Division, Minnesota Mining and Manufacturing Co., will serve as vice-chairman and second vice-chairman, respectively.

(Continued on page 10A)

IMPORTANT business transacted by the 33 Section and Chapter officers and committee chairmen at the Midwestern local activities meeting in Chicago, December 4, 1959, included the decision to request Council to approve division of the Region (with 12 Sections and Chapters, the Society's largest) into two groups. For details, see news item, this page.

JOINT meeting of IES Southern California Section and American Society of Heating, Refrigerating and Air Conditioning Engineers, attended by 319, featured panel on "Integration of Lighting and Air Conditioning in Buildings." Panel, shown here, l. to r.: K. H. Neptune, architect, Edward Frumhoff, electrical engineer; Al Levine, mechanical engineer; Art Clark, City of Los Angeles; Sidney Hill, electrical contractor; Murray Quin, Day-Brite Lighting, Inc.; Frank Parks; Paul Lavigne, Owens-Corning Fiberglas Co.; Robert Lambert, air diffusion engineer and Southern California Section program chairman, J. S. Hamel.

FRANK LEE, left, immediate Past Chairman of the Southern California Section, receives surprise gift from Section, presented by Vice Chairman, Edward Balogh. Presentation was made at joint meeting of Section and the American Society of Heating, Refrigerating and Air Conditioning Engineers.

(Continued from page 9A)

Mr. Perry has also been named to head the Division's Planning Committee which will develop plans for the initiation of Division projects and draft recommendations for an industry-wide program. The presentation of this committee report will highlight the Division's first proposed convention in Hot Springs, Va., next June.

Other Divisions to be organized in connection with NEMA's new operation include: consumer products, lighting equipment, industrial equipment, building equipment, wire and cable, generation, transmission and distribution equipment and industrial electronics and communications equipment.

Office Environment Surveyed

Results of a survey on the "Physiological Factors Governing Office Environment," in 1974 companies, have recently been made public by the National Office Management Association. The 14-page report of the survey, which studied changes that factors such as lighting, air conditioning, sound control and music have produced in the modern office, is available from the National Office Management Association, 1931 Old York Road, Willow Grove, Pa., at $2 per copy.

Some of the reported results show that 75 per cent of the organizations questioned have sound-conditioned offices. Of these, 43 per cent list improved employee morale; 29 per cent, increased accuracy; 16 per cent, increased work volume; 4 per cent, decrease in loss of employee time and 4 per cent, decreased turnover as directly traceable to noise reduction.

Air conditioning has been installed in 72 per cent of the offices studied; pastel painted walls are preferred by 77 per cent of the respondents.

Twenty years ago, the survey found, incandescent lighting was used in most offices. Today, 83 per cent of the NOMA sample offices are equipped with fluorescent lighting.

Office music systems were found in 18 per cent of the 1974 offices, and it was reported that music is successful in reducing fatigue and monotony in certain types of office work.

Concluding the report is the information that the National Office Management Association Standard N7.2, which allows 60-80 square feet of space per person for the general office area, is growing in popularity. Sixty-two per cent of the companies surveyed reported that they are using this Standard in allocation of office space.

Emphasis in today's office is on good lighting and ventilation, as well as cheerfulness and attractiveness. The incorporation of the many physiological features listed above has made the modern office a most pleasant place in which to work.

Industrial Service Association Announces Change in Name

The National Industrial Service Association, Inc. (NISA), as of April 1, 1961, will be known, officially, as the Electrical Apparatus Service Association, Inc. (EASA), according to a recent announcement by the organization's board of directors.

Effective date of the new name was set for 1961 to enable many of the member companies to use their stock of advertising and stationery supplies with the NISA name and emblem.

NISA was founded in 1933 as the National Industrial Electrical Service Association, but the word "Electrical" was subsequently dropped to attract membership from the mechanical service industries. Although these companies have not been eligible for Association membership for many years, the word "Electrical" was never restored.

An increasing demand from the membership for a more descriptive name is responsible for the present change.

British Exhibition to be Held At New York Coliseum

The newest developments in British industry, technology, science and culture will be displayed in the New York Coliseum next June 10-16.

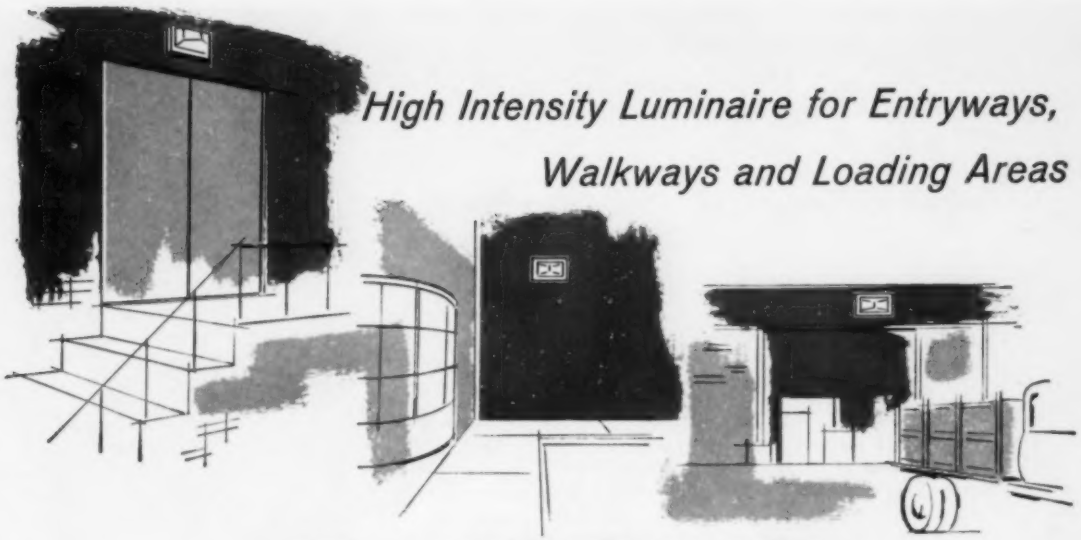
The British Exhibition, sponsored by the Federation of British Industries with the backing and support of the British government, will feature both consumer and capital goods, with the electrical and electronics industry expected to make one of the most extensive showings. A special display by the British government will undoubtedly be another highlight of the show.

Nela Park, Site of Advanced Lighting Conference

Men experienced in the lighting industry gathered at the General Electric Lighting Institute, Nela Park, Cleveland, for a five-day conference on advanced lighting techniques.

The program, which began on Janu-

(Continued on page 13A)



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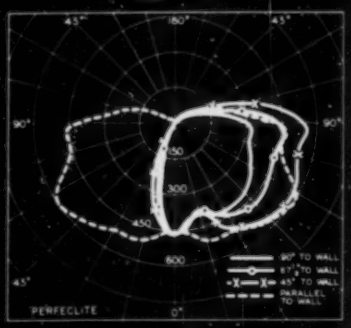

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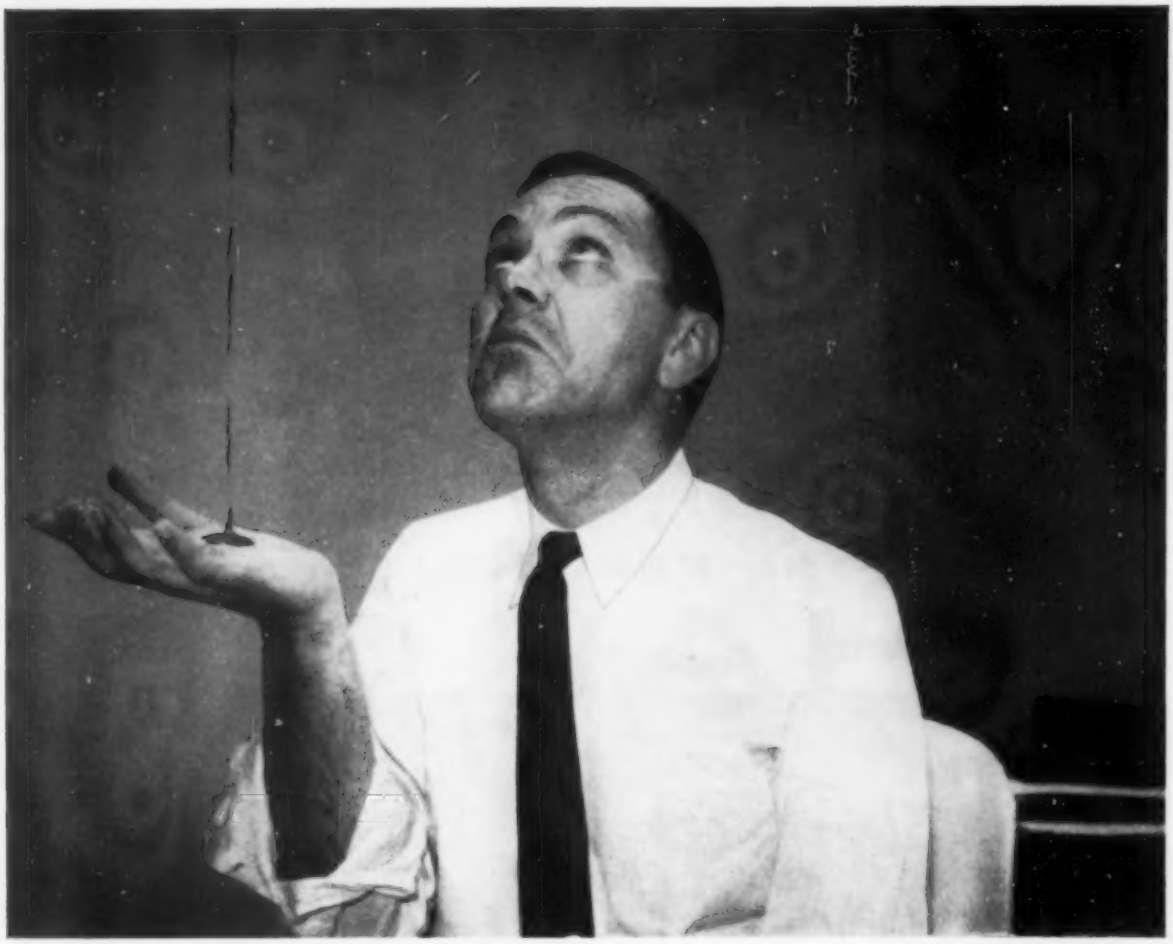

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(*Continued from page* 10A)

ary 18, included careful consideration of such topics as lighting for selling, lighting for offices and schools and the present and future status of industrial lighting. In addition, subjects of a more general nature were reported upon and discussed. There was, for example, a session devoted to new and improved light sources.

Attendants were encouraged to actively participate in the program and toward this end an afternoon was devoted to conferences on requested subjects.

Live Better Electrically Drops TV Advertising for Magazines

The Live Better Electrically program of the Edison Electric Institute has announced the cancellation of its proposed daytime network television and local spot TV advertising for 1960, in order to increase concentration in national consumer magazines. The change in advertising schedule, involving almost $1½ million, was announced by George Ousler, Duquesne Light Co., Pittsburgh, chairman of the Live Better Electrically Policy Committee.

Reason for the change in media, according to Mr. Ousler, was that the Live Better Electrically advertising budget did not permit effective coverage of two major national media.

Reallocated TV funds will be used for five full-color spreads in *Life* magazine, supplementing the six single-page ads originally scheduled for the magazine.

The aim of the Live Better Electrically advertising program is to provide a background for local selling on the LBE theme. Lighting, full housepower, electrical appliances and Medallion Homes will be featured during the year.

National Wiring Bureau Launches Two New Periodicals

Publication program of the National Wiring Bureau for 1960 includes the issuance of two new periodicals, *Wiring Promotion Reporter* and *Profit Idea Digest*. These replace the Bureau's former publications, *Adequate Wiring Reporter*, *Housepower Idea Digest* and *Commercial Wiring Idea Exchange*.

Wiring Promotion Reporter will be similar to the former *Reporter*, except that it will be aimed toward an audience of industry leaders. *Profit Idea Digest*, to be edited specifically for electrical contractors, will contain ideas on both residential and commercial wiring profit.

Eight issues of each periodical will be published each year. Bulk subscription costs are 85 cents per year for the *Reporter*, 40 cents per year for the *Digest*.

(*Continued on page* 16A)

SCHEDULED EVENTS

February 22-25, 1960—National Rural Electric Cooperative Association (Annual Meeting), St. Louis, Mo.

February 25-26, 1960—Annual National Wiring Sales Conference, Warwick Hotel, Philadelphia, Pa.

March 3-4, 1960—Illuminating Engineering Research Institute, Research Symposium, Hotel Sheraton Park, Washington, D. C.

March 6-9, 1960—Fifth National Electrical Industries Show, New York City Coliseum, New York, N. Y.

March 10, 1960—Council Executive Committee Meeting, Illuminating Engineering Society, New York, N. Y.

March 23-26, 1960—Tenth Electrical Industry Show and Lighting Exposition, Shrine Exposition Hall, Los Angeles, Calif.

April 5-7, 1960—Building Research Institute, Spring Conferences, Statler-Hilton Hotel, New York, N. Y.

April 11-12, 1960—Inter-Society Color Council, Philadelphia Museum College of Art, Philadelphia, Pa.

April 20, 1960—Council Executive Committee Meeting, Illuminating Engineering Society, Memphis, Tenn.

April 21-22, 1960— South Central—Southeastern Regional Conference, IES, Hotel Peabody, Memphis, Tenn.

April 25-26, 1960—Southwestern Regional Conference, IES, Robert Driscoll Hotel, Corpus Christi, Texas.

April 28-29, 1960—Inter-Mountain Regional Conference, IES, Mountain Shadows Resort, Scottsdale, Ariz.

May 1-5, 1960—National Association of Electrical Distributors, Dallas, Texas.

May 4-5, 1960—South Pacific Coast Regional Conference, IES, Ambassador Hotel, Los Angeles, Calif.

May 9-10, 1960—Pacific Northwest Regional Conference, IES, Benjamin Franklin Hotel, Seattle, Wash.

May 10-12, 1960—American Institute of Electrical Engineers (Farm Electrification Conference), Sheraton-Fontenell Hotel, Omaha, Nebr.

May 12-13, 1960—Midwestern Regional Conference, IES, Sheraton Martin Hotel, Sioux City, Ia.

May 16-17, 1960—Great Lakes Regional Conference, IES, Hotel Carter, Cleveland, Ohio.

May 23-26, 1960—Design Engineering Show, Coliseum, New York, N. Y.

June 8-9, 1960—Northeastern Regional Conference, IES, Wentworth-by-the-Sea, Portsmouth, N. H.

June 10-26, 1960—British Exhibition (Industry, Technology, Science, Culture), New York City Coliseum, New York, N. Y.

June 12-15, 1960—American Society of Heating, Refrigerating and Air Conditioning Engineers, Annual Meeting, Vancouver, B. C.

June 13-14, 1960—Canadian Regional Conference, IES, Nova Scotian Hotel, Halifax, N. S.

June 16, 1960—Council Meeting, Illuminating Engineering Society, New York, N. Y. Members are free to attend meetings of Council as guests.

August 8-12, 1960—American Institute of Electrical Engineers, Pacific General Meeting, San Diego, Calif.

September 6-16, 1960—Production Engineering Show, Navy Pier, Chicago, Ill.

September 11-16, 1960—Illuminating Engineering Society, National Technical Conference, Penn-Sheraton Hotel, Pittsburgh, Pa.

September 28-30, 1960—Canadian Electrical Manufacturers Association, Sheraton-Brock Hotel, Niagara Falls, Ont.

October 9-14, 1960—American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 23-27, 1960—National Electrical Contractors Association, Las Vegas, Nevada.

November 14-18, 1960—National Electrical Manufacturers Association (Annual Meeting), Traymore Hotel, Atlantic City, N. J.

November 27-December 2, 1960—American Society of Mechanical Engineers, Annual Meeting, Statler-Hilton Hotel, New York, N. Y.

December 12-15, 1960—Industrial Building Exposition & Congress, New York City Coliseum, New York, N. Y.

January 24-27, 1961—Society of Plastic Engineers, Inc., (17th Annual Technical Conference) Shoreham and Park-Sheraton Hotels, Washington, D. C.

IES Membership Directory—See Index to 1959

Your copy of the Personnel Index in the Annual IES Indexes, published as Section II of the January 1960 issue of IE, is a valuable reference for addresses and business affiliations of IES officers and committee personnel — active Society members. Save your Index for use in IES business all through the coming year.

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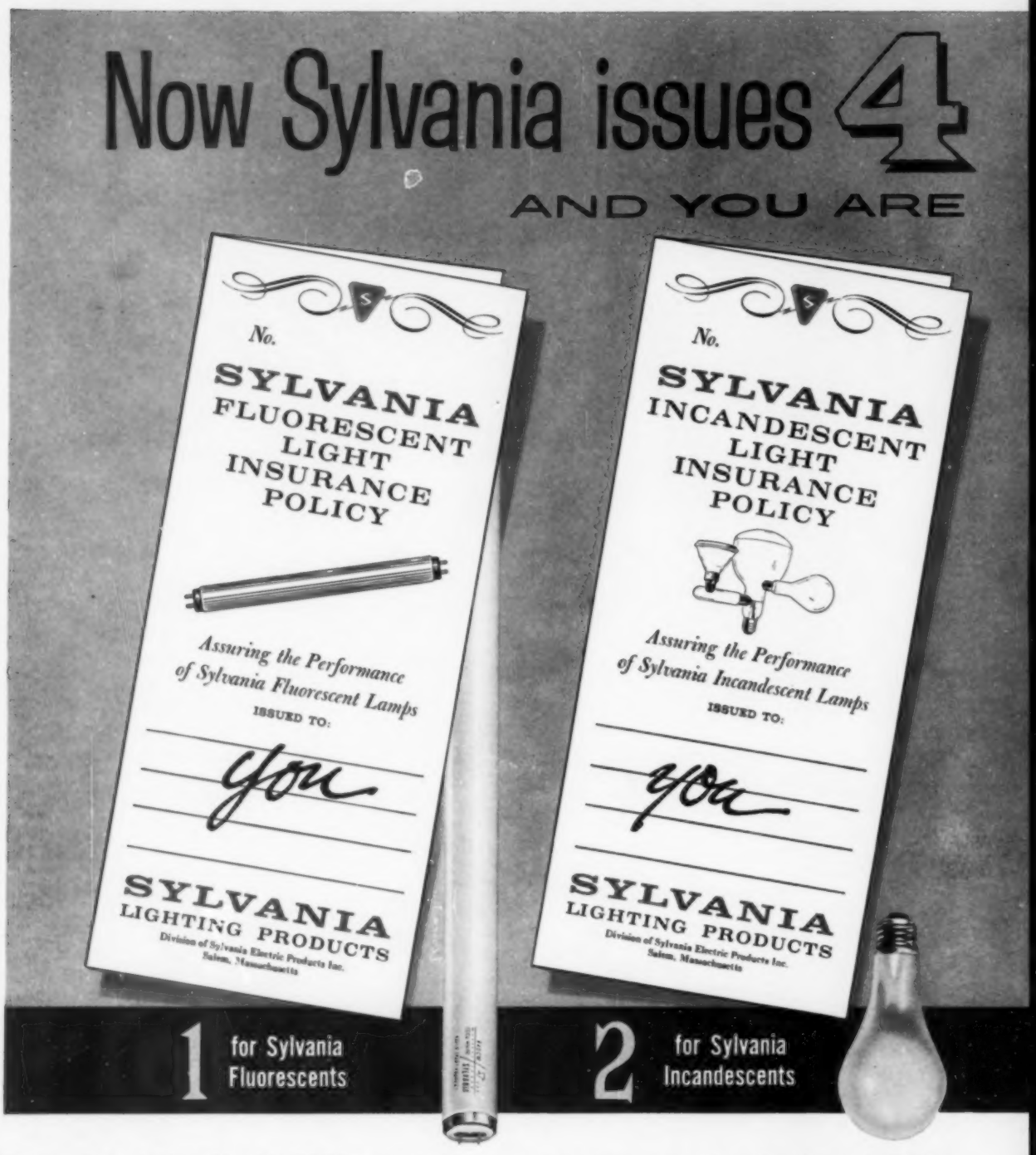

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(*Continued from page 15A*)

Rates for under five copies are $1.50 and $1.00, respectively.

A free copy of the *Digest* will be included with every issue of the *Reporter*.

Esso Foundation Gives $5000 Grant to Case Institute

An unrestricted grant of $5000 has been awarded to Case Institute of Technology, Cleveland, by the Esso Education Foundation, for stimulation and improvement of science teaching in the Institute's undergraduate engineering departments.

Conditions of the grant allow it to be used to defray expenses of staff members for attendance at scientific meetings, for research projects or for the purchase of special laboratory equipment and books.

The $5000 grant to Case is part of $485,000 awarded by the Foundation this year to fifty-four colleges and universities and six special projects in 25 states.

IES Canadian Region Publishes Newsletter

One important activity of the Canadian Regional Public Relations and Information Committee for 1959-1960 is the publication of a regional newsletter. The first issue of the publication (January) calls attention to the new IES Applied Lighting Contest; reports the future publication of a report on home lighting, "Lighting Keyed to Today's Homes," a revised "Recommended Practice of Office Lighting" and a project underway to develop a Recommended Practice for Service Station Lighting.

Ron Selater, Regional PR&I Chairman, is editing the newsletter, which will feature current IES news of both national and regional interest.

Obituary

Joseph E. Kewley, widely known as a former General Electric vice president and general manager, died in Florida on January 4 at the age of 76.

Mr. Kewley, a lawyer by profession, was made assistant general manager at Nela Park, Cleveland, in 1920, following ten years' service in G-E's Legal Dept. Five years later he was advanced to general sales manager of the former National Lamp Works. On January 1, 1931 Mr. Kewley became general manager of the newly created Incandescent Lamp Dept. (now the Lamp Division) and on May 25, 1934 he was appointed vice president, a capacity in which he served until retiring on January 1, 1945.

Since his retirement Mr. Kewley and his wife had been dividing their time between Cleveland and Florida.

PLANNING for portable lamp design contest are, left to right, Cecile Hayward, Home Furnishings Coordinator, *Living for Young Homemakers*; Howard Levine, student at Parson's School of Design and Morris Thau, chairman of the sponsoring National Lamp Design Contest Committee of the Lamp and Shade Institute of America. Designed to stimulate interest in portable lamp design and to emphasize the importance of portables in home lighting and decorating, the contest, open to students of industrial and interior design, carries $1000 in cash prizes. Contest judges include Miss Hayward; Myrtle Fahsbender, Westinghouse Residential Lighting Director; James Amster, AID; Mary Davis Gillies, *McCall's* magazine; Cynthia Kellogg, *New York Times*; Harriet Morrison, *New York Herald-Tribune* and Edward J. Wormley, AID and IDI.

ABOUT PEOPLE

The end of a term as IES President marked the beginning of a new professional advance for **George J. Taylor,** 1958-1959 Society President who, as of January 1, was named Vice President in Charge of Research, Development and Marketing for Day-Brite Lighting, Inc., in a move to strengthen the company's top management organization. In line with this promotion, Mr. Taylor is moving his offices from the Day-Brite headquarters in New York City to the company's executive headquarters in St. Louis.

Mr. Taylor joined Day-Brite in 1947, working on national accounts in association with architects, consulting engineers and electrical construction firms. Shortly thereafter, he was made the firm's first regional sales manager, covering the northeastern section of the U.S.

Paralleling his rise at Day-Brite are Mr. Taylor's activities with IES. From 1952 to 1954, he was Northeastern Regional Vice President and in 1954-1955 was elected Treasurer, from which office he eventually acceded to the Presidency. Mr. Taylor's qualifications for his new position at Day-Brite, he feels, are in large measure due to his IES activities which brought him closer contact with and a wider perspective on all problems and viewpoints in the lighting field, from basic research to the sale of equipment.

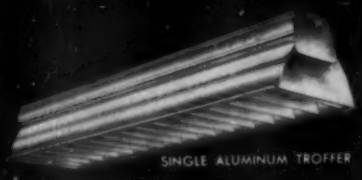
Two promotions within the Westinghouse Lamp Division, Bloomfield, N. J. have been recently announced. Named as assistant director of research is **Dr. Russell H. Atkinson** who joined the Division as a research engineer in 1951 and became section manager of the metals group in 1956. **Edward T. Adams** is the new manager of Rayescent Engineering (electroluminescence).

The appointment of two divisional vice presidents was announced by Frank J. Healy, president of Sylvania Lighting Products, Salem, Mass., a division of Sylvania Electric Products Inc. **Garlan Morse** becomes vice president and general manager — large lamp products and **Paul F. Cameron** will be vice president and general manager — photolamp and

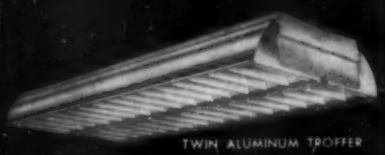
(*Continued on page 18A*)

New Aluminum Troffers for POWER-GROOVE . . .

COMFORTABLE, High Footcandle Lighting at LOWER COST than Ever Before Possible



SINGLE ALUMINUM TROFFER



TWIN ALUMINUM TROFFER

Another Lighting First . . . Miller has just broken through some long standing cost barriers to COMFORTABLE, high footcandle lighting for Offices, Stores, and Public Buildings. Now, you can obtain or provide today's needed higher levels of light at *much* lower cost.

For Example . . . The lighting installation pictured is designed to maintain 120 footcandles in this 60′ x 80′ general office area. Fixtures are Miller's new Twin Aluminum Troffers—2′ x 8′ units with Power Groove Lamps. Compared with conventional, 2′ x 4′ door type recessed systems using 40w Rapid Start Lamps, and providing comparable footcandles and comfort: this new Power Groove system *requires only ¼ as many fixtures*, and *has an initial installed cost 30%-38% lower. Annual Owning and Operating cost figures 14%-18% less.* And, fewer fixtures needed means a less cluttered, more pleasing ceiling appearance. Here, 34% more ceiling area is available for acoustical treatments.

Substantial savings can be realized for both relighting and new construction . . . wherever comfortable, high footcandle lighting is desired. Let us prove to you how such savings are possible for this and other typical installations. Simply *fill out and mail the coupon.* Or, contact your Miller Representative.

MAIL TODAY

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THE MILLER COMPANY, Meriden, Conn.

☐ I'd like additional information on how I can obtain comfortable, high footcandle lighting at lower cost with Miller Aluminum Troffers.

☐ Have Your Field Representative contact me.

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Company_____

Street_____

City_____ State_____

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SINCE 1844

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THE miller COMPANY

MERIDEN, CONNECTICUT

1960 Regional Conferences—IES

Region	Date and Place	Chairman
South Central and Southeastern	April 21-22 Peabody Hotel Memphis, Tenn.	J. F. Fletcher Standard Electric Co. 876 Vance Ave. Memphis, Tenn.
Southwestern	April 25-26 Robert Driscoll Hotel Corpus Christi, Texas	B. L. Guess, Jr. 1210 York Ave. Corpus Christi, Texas
Inter-Mountain	April 28-29 Mountain Shadows Resort Scottsdale, Ariz.	D. L. Huff Arizona Public Service Co. Phoenix, Ariz.
South Pacific Coast	May 4-6 Ambassador Hotel Los Angeles, Calif.	William Shalda Shalda Mfg. Co., Inc. P. O. Box 507 Burbank, Calif.
Pacific Northwest	May 9-10 Benjamin Franklin Hotel Seattle, Wash.	G. D. King Sylvania Electric Products 3466 E. Marginal Way Seattle, Wash.
Midwestern	May 12-13 Sheraton-Martin Hotel Sioux City, Ia.	Mark Lee and C. R. Tracy Iowa Public Service Co. Sioux City, Ia.
Great Lakes	May 16-17 Carter Hotel Cleveland, Ohio	R. D. Churchill General Electric Co. Nela Park, Cleveland, Ohio
Northeastern	June 8-9 Wentworth-By-the-Sea Portsmouth, N. H.	C. M. Holden Champion Lamp Works 330 Lynnway Lynn, Mass.
Canadian	June 13-14 Nova Scotian Hotel Halifax, N. S.	Henry Lushington Canadian G-E Co. Halifax, N. S.

(*Continued from page* 16A)

special products, both with headquarters in Salem. Another appointment named **John E. Rhodes** director of operations analysis for Sylvania Electric Products Inc. Mr. Rhodes, formerly vice president —operations of Sylvania Electric (Canada) Ltd., will have over-all responsibility for operations analysis on a company-wide basis. He will make his headquarters in New York City.

Guy de Leuze Co., recently settled in new quarters at 1923 Bryant St., San Francisco, Calif., has announced the appointment of **J. Sartuche** as Sacramento and San Joaquin Valley representative.

Philip R. Milroy has been named manager of engineering of the General Electric Outdoor Lighting Dept., Hendersonville, N. C. In his new capacity Mr. Milroy is responsible for all phases of the department's engineering program on street and highway lighting luminaires, floodlighting, ballasts, transformers, photoelectric controls and lighting equipment required for defense purposes. He succeeds **Charles J. Meloun,** recently appointed marketing manager of the department. G-E also announced the appointment of **Henry J. Chanon** as manager of the Carolinas sales district of the Large Lamp Dept. He succeeds **Glenn E. Park,** who will serve in a consulting capacity until his retirement August 1. Mr. Chanon, working out of Charlotte, N. C., lists among his new responsibilities the sale of G-E lamps for general lighting of homes, commerce and industry in the Carolinas.

Ivan S. Coggeshall, former assistant vice president of the Western Union Telegraph Co., has been appointed manager of technical operations services for the American Institute of Electrical Engineers. Operating out of AIEE headquarters in New York City, Mr. Coggeshall will be responsible for staff services related to the work and program of the Technical Operations Dept., its six divisions and 56 technical committees. Also announced by AIEE was the selection of **James F. Fairman,** senior vice president, Consolidated Edison Co., New York City, as recipient of the 1959 Edison Medal. The citation accompanying the medal is "for outstanding performance in improving the design of large electric power systems; for farsighted leadership in atomic power development; and for unremitting efforts to improve the engineering profession."

William E. Gundelfinger has been named administrative assistant and director of manufacturing of Day-Brite Lighting, Inc., St. Louis, according to a recent announcement. Mr. Gundelfinger recently resigned as president of the Dazey Corp., St. Louis. Also announced was the appointment of **John F. Ryan** as sales training manager. Mr. Ryan was formerly director of sales training at the Kiekhaefer Corp., Fond du Lac, Wis. and during a 15-month period he managed and organized the Dale Carnegie Sales Course in St. Louis.

Prescolite Manufacturing Corp., Berkeley, Calif., has named **Stan Heywood** as national marketing director. Among the duties of the newly-created post is the organization of regional and national sales meetings with architectural and engineering groups as well as with distributors and contractors, as part of a new national merchandising program. In addition, Mr. Heywood who will make his headquarters in Neshaminy, Pa., will participate as the company's public-relations representative in the functions of associated trade groups. Prescolite also announced the appointment of **Donald Congdon** as representative for the Colorado-Wyoming area. Mr. Congdon, working out of offices in Ladewood, Colo., replaces **Al Thompson,** who has been transferred to the home offices with responsibilities for sales and service in the San Francisco Bay region.

The promotion of **George J. Fauser** to manager—service station lighting sales has been announced by John A. McDougall, vice president and sales manager of Revere Electric Mfg. Co., Chicago, Ill. Mr. Fauser, whose experience includes 13 years in the electrical industry, will head up the sales of Revere equipment for service station lighting.

The promotion of **Gordon A. West** to lighting glassware sales representative for the eastern sales district has been announced by Corning Glass Works, Corning, N. Y. Mr. West's territory includes New Jersey, eastern Pennsylvania, Maryland, Delaware, the District of Columbia

(*Continued on page* 32A)

THESE AUTHORIZED LIGHTOLIER DISTRIBUTORS STOCK CALCULITES BY LIGHTOLIER

ALABAMA
Birmingham:
Mayer Elec. Sup. Co.
ARIZONA
Phoenix:
Brown Wholesale Elec.
CALIFORNIA
San Francisco:
California Elec. Sup. Co.
COLORADO
Denver:
Central Elec. Sup. Co.
CONNECTICUT
Bridgeport:
B. M. Tower Co., Inc.
Hartford:
Beacon Light & Sup. Co.
New Haven:
Grand Light & Sup. Co.
New London:
United Elec. Sup. Co.
Stamford:
Merle Co.
Waterbury:
Starbuck Sprague Co.
Suburban Supply Co.
DISTRICT OF COLUMBIA
Washington:
Maurice Elec. Sup. Co.
National Elec. Wholesalers
FLORIDA
Miami:
Fleisig's White. Hdwe. Co.
GEORGIA
Atlanta:
Electrical Wholesalers
Noland Co.
Augusta:
Hall Electric Sup. Co.
ILLINOIS
Chicago:
Efengee Elec. Sup. Co.
Englewood Elec. Sup. Co.
Horlo Elec. Sup. Co. Inc.
Hyland Elec. Sup. Co
Metropolitan Elec. Sup.
Steiner Elec. Co.
Wholesale Elec. Sup. Co.
Elgin:
Fox Elec. Sup. Co.
Rockford:
Englewood Elec. Sup. Co.
Springfield:
Springfield Elec. Sup. Co.
INDIANA
Ft. Wayne:
Hinkman-Farrell's Co.
Gary:
Englewood Elec. Sup. Co
South Bend:
Englewood Elec. Sup. Co.
IOWA
Des Moines:
Weston Lighting, Inc.
KANSAS
Kansas City:
W. T. Foley Elec. Co.
KENTUCKY
Louisville:
Henry J. Ruff Co.
LOUISIANA
Baton Rouge:
Electrical Wholesalers Inc.
New Orleans:
Interstate Elec. Co.
MAINE
Bangor:
Standard Elec. Co.
Portland:
Holmes Elec. Supply Co.
MARYLAND
Baltimore:
Excello Public Serv. Corp.
Salisbury:
Artcraft Elec. Sup. Co.
MASSACHUSETTS
Boston:
Mass. Gas & Elec. Light Co.
Henry L. Wolfers, Inc.
Pittsfield:
Carr Supply Co.
Springfield:
Eastern Elec. Sup. Co.
Worcester:
Atlantic Elec. Sup. Co.
Benjamin Elec. Sup. Co.
MICHIGAN
Detroit:
Madison Elec. Co.
Michigan Chandelier Co.
Flint:
Royalite Co.
Grand Rapids:
Purchase Elec. Sup. Co.
Jackson:
Electric Wholesale Sup. Co.
Pontiac:
Standard Elec. Co.
Saginaw:
Schuerholz Elec. Co.
Standard Elec. Sup. Co.
MINNESOTA
Duluth:
Northern Elec. Sup. Co.
Minneapolis:
Charles A. Anderson & Co.
Northland Elec. Sup. Co.
St. Paul:
Lee Elec. Co.
MISSOURI
Kansas City:
Glasco Elec.
St. Louis:
M. K. Clark
MONTANA
Great Falls:
Glacier State Elec.
NEBRASKA
Lincoln:
White Elec.
Omaha:
Electric Fix. & Sup. Co.
NEVADA
Reno:
Western Elec. Dists. Co.
NEW HAMPSHIRE
Portsmouth:
Mass. Gas & Elec. Light Co.
NEW JERSEY
Atlantic City:
Franklin Elec. Sup. Co.
Cherry Hill-Delaware Township:
Flynn's Camden Elec. Fix. Co.
NEW MEXICO
Albuquerque:
The Lighting and Main. Co.
NEW YORK
Binghamton:
Freyja Elec. Sup. Co.
Buffalo:
Buffalo Incand. Light Co. Inc.
Niagara Falls:
Nyvan Supplies Inc.
NEW YORK (cont.)
Poughkeepsie:
Electra Sup. Co.
Rochester:
Rowe Electric Sup. Co.
Syracuse:
Superior Elec. Serv.
NORTH CAROLINA
Charlotte:
Independent Elec. Sup. Co.
Durham:
Noland Co.
Greensboro:
Elec. Sup. & Equip. Co.
Kinston:
Kinston Elec.
Winston Salem:
Noland Co.
NORTH DAKOTA
Fargo:
Northwest Elec. Sup. Inc.
OHIO
Akron:
The Sacks Elec. Sup. Co.
Canton:
Electric Sales Co.
Cincinnati:
B. & B. Elec. Co.
F. D. Lawrance Electric Co.
Richards Elec. Sup. Co.
Cleveland:
The H. Leff Electric Co.
Midland Elec. Co.
Columbus:
Elgee Elec. Co.
The Loeb Elec. Co.
Dayton:
Buellman Elec. Co.
Springfield:
The W. W. Elec. Co.
Toledo:
Gross Elec. Fix. Co.
Youngstown:
Mart Industries
OKLAHOMA
Oklahoma City:
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Portland:
Baker-Barken Co.
Malloy Robinson Co.
PENNSYLVANIA
Allentown:
Coleman Elec. Co.
Erie:
Kraus Elec. Co.
Harrisburg:
Fluorescent Sup. Co.
Hazleton:
Power Elec. Co. Inc.
Kingston:
Anthracite Elec.
New Castle:
Midwestern Elec. Co.
Philadelphia:
Ace Lighting Fix. Co.
Gold Seal Elec. Sup. Co.
Sylvan Elec. Fix. Co.
Pittsburgh:
Allied Elec. Sup. Co.
Argo Life Studios
Reading:
Coleman Elec. Co.
Scranton:
Lewis & Reif, Inc.
Uniontown:
Pioneer Electric Dist.
RHODE ISLAND
Pawtucket:
Major Elec. Sup. Co.
Providence:
Leavitt Corson Co.
SOUTH CAROLINA
Columbia:
Capitol Elec. Sup.
Noland Co.
Greenville:
Sullivan Hdwe. Co.
SOUTH DAKOTA
Watertown:
J. H. Larson Elec. Co.
TENNESSEE
Nashville:
Nashville Elec. Sup. Co.
TEXAS
Austin:
Southern Electric Sup. Co.
Dallas:
Rogers Elec. Sup. Co.
Ft. Worth:
Anderson Fixture Co.
Houston:
Gross Electric Supply
Marlin Associates
Southern Electric Supply Co.
Lubbock:
Home G. Massey & Co.
San Antonio:
Southern Equip. Co.
Strauss-Frank Co.
UTAH
Salt Lake City:
Artistic Lighting
VIRGINIA
Arlington:
Dominion Elec. Sup. Co. Inc.
Noland Co.
Lynchburg:
Mid-State Elec. Sup. Co., Inc.
Norfolk:
Noland Co.
Roanoke:
Noland Co.
WEST VIRGINIA
Huntington:
West Virginia Elec. Co.
Wheeling:
The Front Co.
WISCONSIN
Appleton:
Moe Northern Co.
Eau Claire:
W. H. Hobbs Sup. Co.
Milwaukee:
Lappin Elec. Co.
Standard Elec. Sup.
WASHINGTON
Seattle:
Seattle Lighting Fix. Co.
ALASKA
Anchorage:
Northern Supply Co.
CANADA
Montreal:
L. D. G. Products, Inc.
The Gray Elec. Co.
Union Electric Sup. Ltd.
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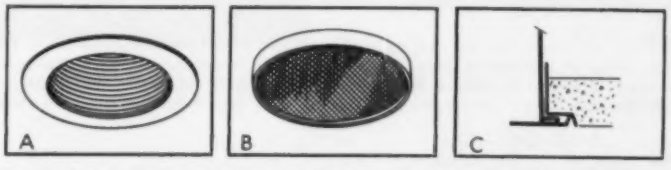
La Cie Martineau Electric Co.
Toronto:
Bevera Elec. Dist.
Toronto Ltg. Studios
HAWAII
Honolulu:
Hawaiian Light & Sup. Co.

For effective downlighting specify CALCULITES by LIGHTOLIER

You can achieve almost any downlighting effect your project requires from this one coordinated, quality group... effectively, efficiently, precisely. The model shown above, for instance, articulates the ceiling-fixture joint with a luminous plastic bezel which extends one inch below ceiling line. The almost "invisible" multi-groove baffle unit (A) gives completely unobstrusive effects. The new low brightness Prismatex lens (B) provides a medium spread of light without glare for specific lighting. Duo-style reversible plaster frames (C) permit round Calculites to fit completely flush to the ceiling line or overlap the ceiling. There are seventeen other models, round and square, for wide, medium or narrow light distribution... in 96 different sizes and finishes.



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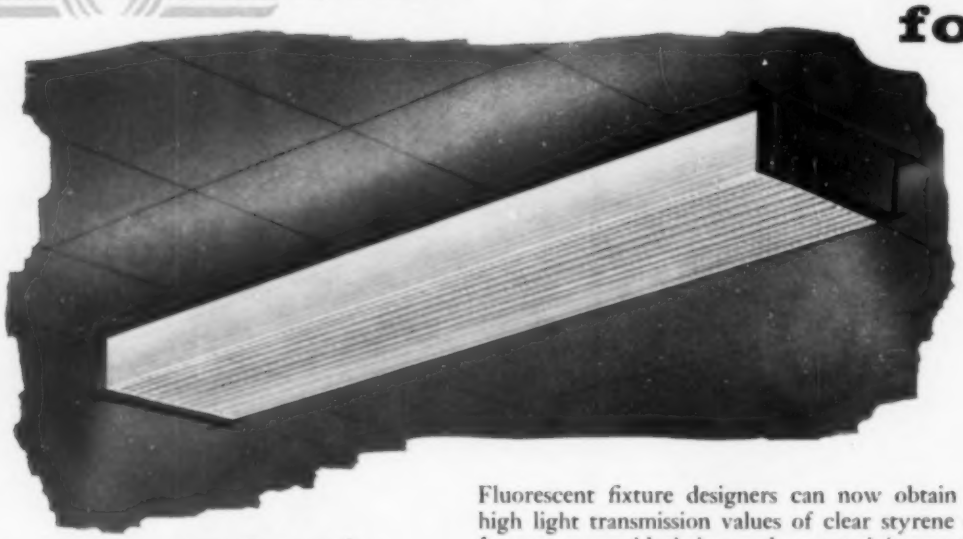
Showrooms: New York, Chicago, Dallas, Los Angeles

SHEFFIELD PLASTICS, INC. Announces for



Directo-Lite*

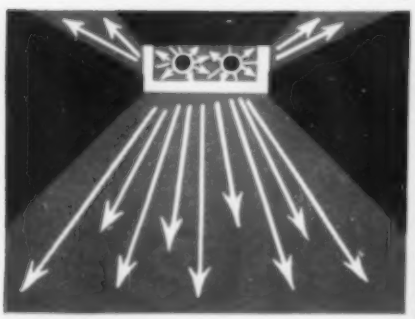
Fluorescent fixture designers can now obtain the high light transmission values of clear styrene diffusers, yet avoid their usual eye-straining surface brightness. Sheffield engineers have succeeded in designing prismatic configurations for these diffusers

*Trade

Directo-Lite Diffusers have a prismatic sidewall of clear styrene, so designed that light emitted by the sides is refracted down onto work area or up to the ceiling, where it reduces ceiling-fixture brightness contrast. Cut-off in the area between 45-degrees and the ceiling is excellent. Glare and bright spots are thus eliminated.

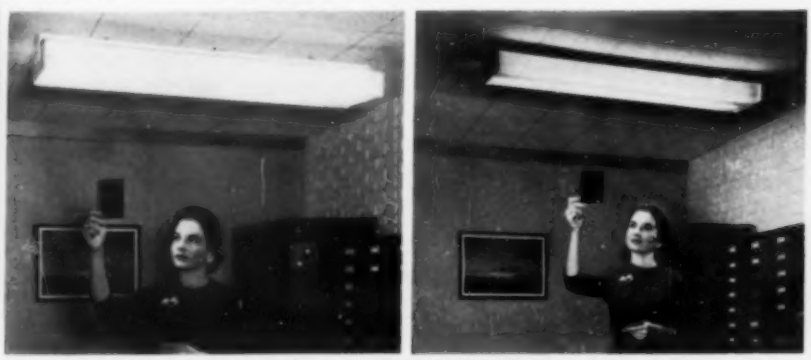
NEW DIRECTO-LITE DESIGN PROVIDES

- Higher Fixture Efficiency
- Increased Down Lighting
- Excellent 45-Degree Cut-Off
- Low Surface Brightness
- Indirect Ceiling Illumination
- Clean Attractive Lines



45-Degree Cut-Off

and more efficient illumination on ceiling and work areas is provided by unique Directo-Lite prismatic design.



Directo-Lite vs conventional clear styrene diffuser. Note low surface brightness, good 45-degree cut-off and cone of light on ceiling refracted through sidewall of Directo-Lite wrap-around at right.

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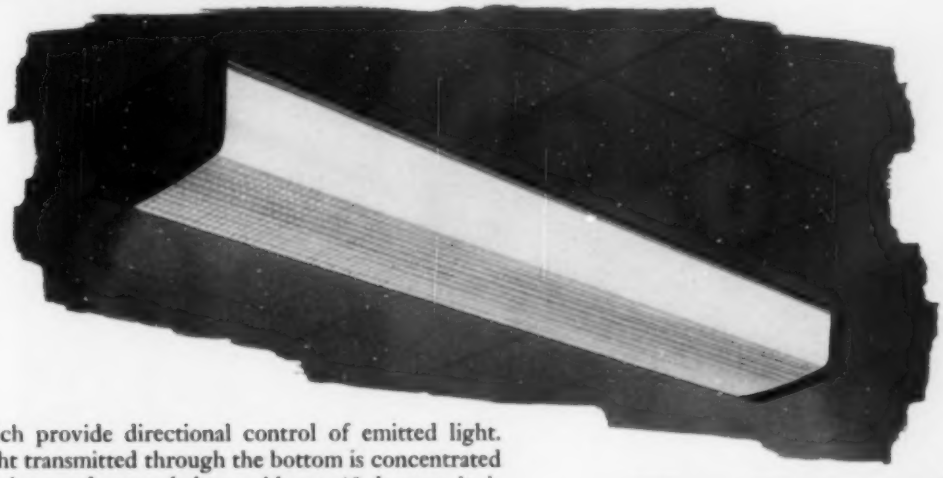
FIRST IN PLASTICS

SHEFFIELD PL

SHEFFIELD,

Two New Wrap-arounds
fluorescent fixtures



which provide directional control of emitted light. Light transmitted through the bottom is concentrated on the work area below. Above 45-degrees it is cut-off sharply, thus increasing fixture efficiency, improving appearance and cutting eyestrain.

Tu-Tone*

mark

Tu-Tone Diffusers combine white, translucent sidewalls with the clear prismatic bottom to give a modern 2-color effect. Sheffield engineers developed a new manufacturing technique to do this – at a cost comparable to conventional single-color styrene diffusers. The process can be used for a wide variety of old or new fixture designs with all types of return legs for hinging purposes.

NEW TU-TONE DESIGN PROVIDES

- **Modern two-color effect at low cost**
- **Increased Down Lighting**
- **Excellent 45-degree Cut-Off**
- **Glare-Free, Low Surface Brightness**
- **Flexibility in Design**
- **Novel Appearance**

Prismatic lens design on bottom of Tu-Tone diffuser directs all emitted light down on work areas, yet prevents glare or bright spots.

Translucent sidewall of new Tu-Tone Diffuser hides light source completely. Note sharp 45-degree cut-off by prismatic lens on bottom.

Sheffield Plastics, Inc.
Sheffield, Mass.
Dept. O1-B

..... Send technical data on Tu-Tone Diffusers.
..... Send technical data on Directo-Lite Diffusers.
..... Have your representative call.

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Company.....
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WRITE FOR FURTHER DETAILS

Find out how you can create entirely new fixture designs, add sales appeal to existing fixtures — at little or no added cost — and increase fixture efficiency and beauty. Complete technical data is readily available. Use the coupon below or write to Sheffield Plastics, Inc., Dept. O1-B, Sheffield, Mass.

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ASTICS, INC.

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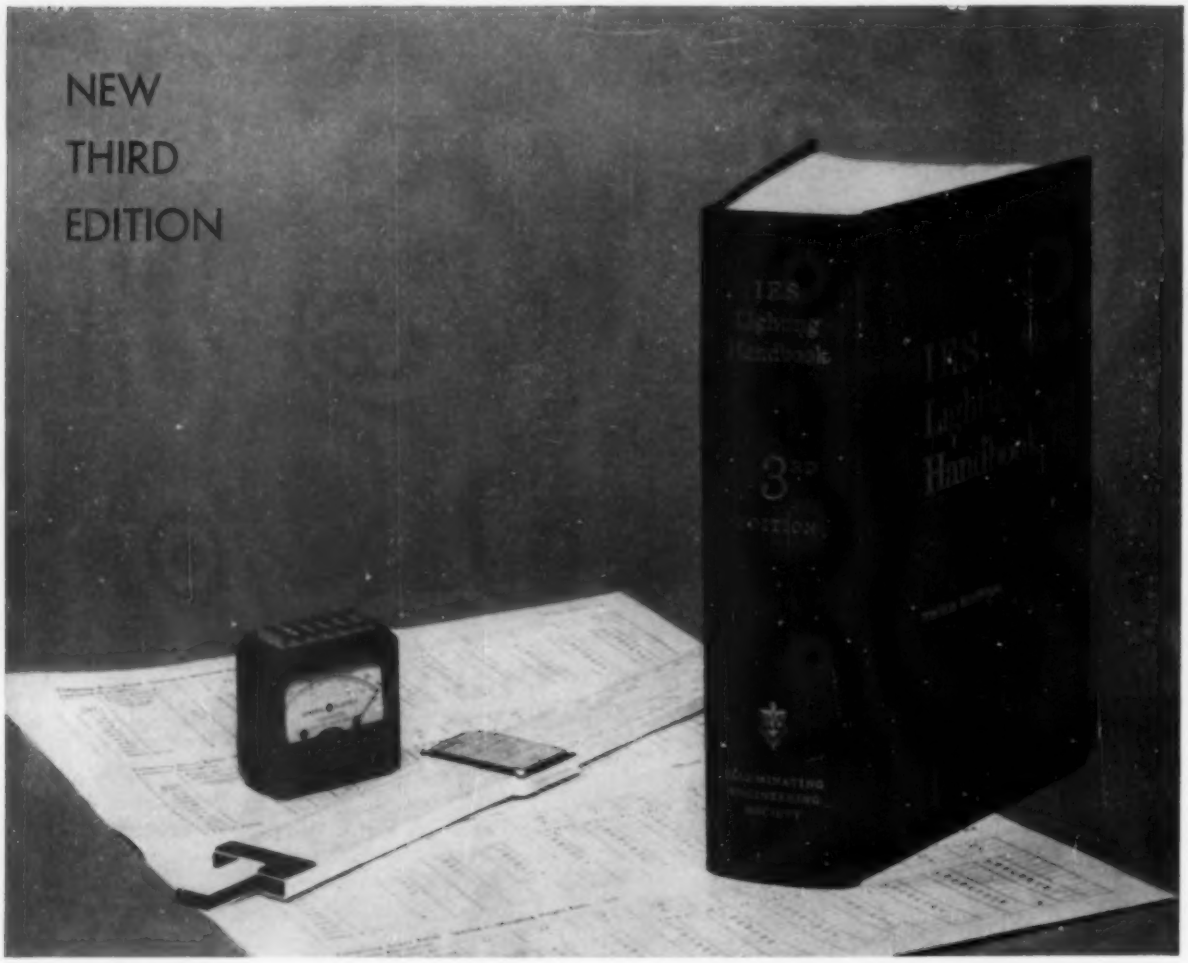

I.E.S. LIGHTING HANDBOOK, New Third Edition

"A complete lighting library in one volume" is how users have described the *I.E.S. Lighting Handbook*, latest edition of which was just published in late March. Over 10,000 copies of this brand-new Third Edition are now being used by people concerned with lighting in all parts of the world.

With lighting rapidly becoming one of our most dynamic industries, these people know that they must have latest basic information of lighting techniques and applications to understand and keep abreast of new developments. In this changing situation, there is no substitute for the new Third Edition even though you may be devoted to your 1952 or even 1947 edition of the old Handbook.

Remember, there is no finer authority for your lighting recommendations and decisions than the Third Edition, *I.E.S. Lighting Handbook*, so be sure your Handbook is the latest.

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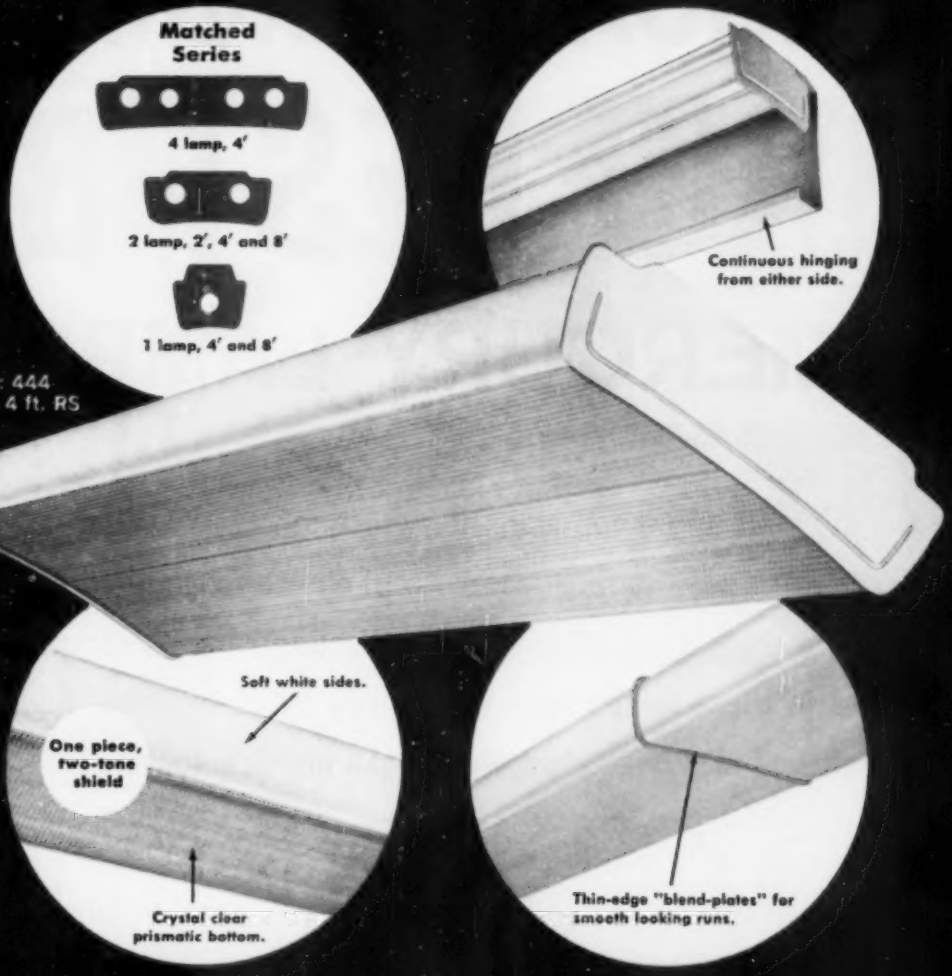
New Gar-Lite Dualens Series*


Matched Series
4 lamp, 4'
2 lamp, 2', 4' and 8'
1 lamp, 4' and 8'
SHOWN: 444
Four-lamp, 4 ft. RS
Continuous hinging from either side.
Soft white sides.
One piece, two-tone shield
Crystal clear prismatic bottom.
Thin-edge "blend-plates" for smooth looking runs.

Sensibly priced lighting with matched series versatility

...overlook the new Gar-Lite Dualens Series. No other low priced, top quality fixture can offer you this matched series versatility — six fixtures, in lengths and lamps to meet every requirement.

And it's hard to equal the many exclusive built-in features found in the Dualens Series... features seldom found even in higher priced fixtures.

* The complete Gar-Lite economy line includes these quality fixtures.

GARCY LIGHTING

Div. of Garden City Plating & Mfg. Co.
2475 Elston • Chicago 47, Ill.

Write for your Gar-Lite brochure today

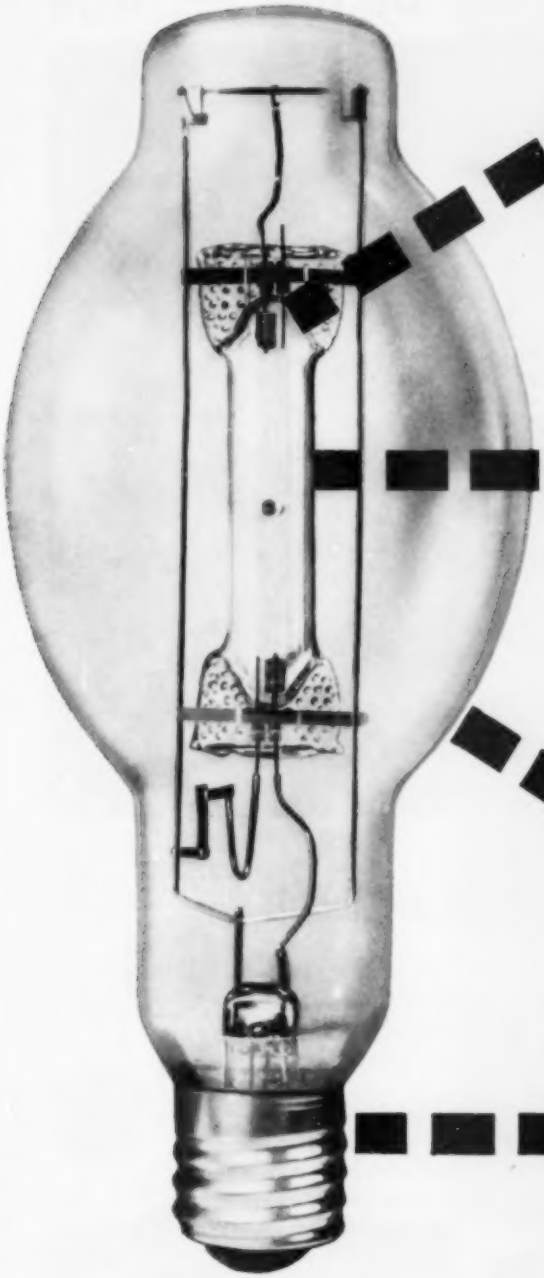
EXCLUSIVE WEATHER LIFEGUARD™ ARC TUBES

YOUR BEST BUY IN MERCURY LAMPS!

By any standard of comparison, new Westinghouse "Lifeguard" mercury lamps are the most economical choice for industrial, street, and parking lot lighting. The exclusive Westinghouse "Lifeguard" arc tubes in these lamps save you money by maintaining high initial light output longer. And, they make possible lower-cost new lighting installations.

In addition to getting more light per dollar, you save on labor and maintenance costs, too, with less frequent lamp changing. And "Lifeguard" lamps are made with famous Westinghouse "Weather Duty" bulb construction for resistance to thermal shock, moisture and all industrial fumes. New Westinghouse "Weather Duty" lamps with "Lifeguard" arc tubes are interchangeable with other types of the same wattage. Make the change today. Contact your authorized Westinghouse lamp agent or nearest Westinghouse sales office.

DUTY™ LAMPS WITH MAKE WESTINGHOUSE



New design electrodes with specially-compounded and locked-in emission material virtually eliminate light-robbing arc tube blackening.

"Lifeguard" arc tube improves lumen maintenance . . . 85 percent of initial light output after 10,000 hours.

First with "Weather Duty" lamps . . . fume-proof and moisture-proof, shock-resistant glass.

Permanent-grip silicone cement holds bases tight for the life of the lamp. Remains strong at high temperatures. No strain on glass.

YOU CAN BE SURE... IF IT'S Westinghouse

Westinghouse Lamp Division · Bloomfield, N. J.

KOPP
Flying Glassware
for specialized requirements of the Jet Age

Illustration Courtesy of TWA—Trans World Airlines

TWA Boeing 707 dome lights are designed and produced by Grimes Manufacturing Company. Special blue lenses, illustrated below, are Kopp engineered.

Kopp Glassware is widely used in Airports, Runways and Aircraft

Blue dome light lenses on jet planes are only one example of many "Flying" glassware products which Kopp designs and makes for specific requirements. Others include instrument panel lighting, navigation lights and warning lights.

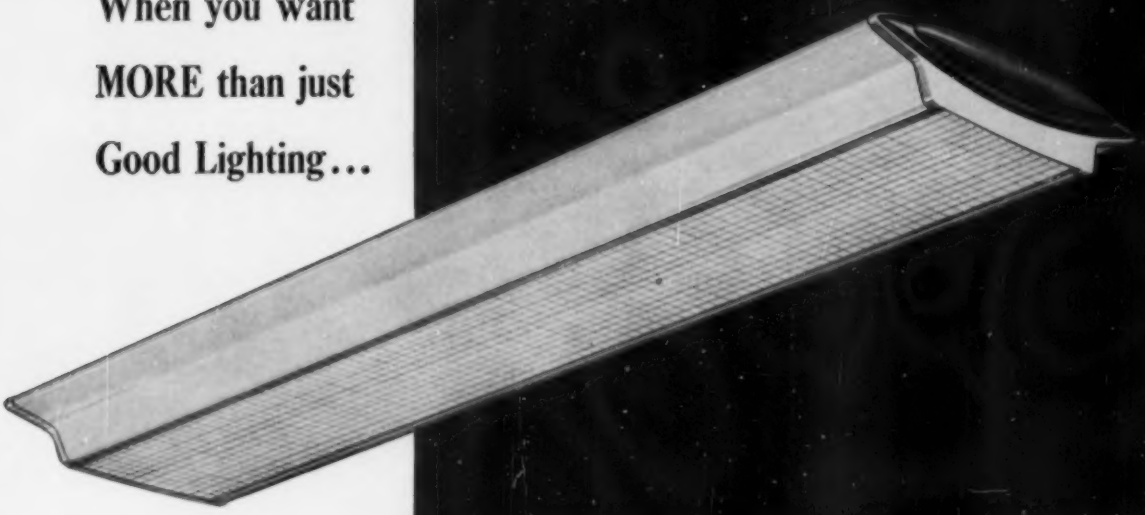
Kopp lenses, color filters and other lighting glassware are specially designed as to dimension, color, shape, beam control, light distribution and various physical properties.

Write us about your special design problems. Sending preliminary drawings, before your design specifications are finalized, will frequently save you time and money. Ask for our brochure on Kopp Engineered Glass.

Kopp Glass, INC.
Swissvale, Pennsylvania

KOPP GLASS

When you want
MORE than just
Good Lighting...



You want

Sylvania's CLASSIC

Series

"Fluorescent lighting fixtures today must do more than provide good illumination. They must also add a distinct element of attractiveness to the ceiling to complement the overall interior décor."

With this concept in mind, Sylvania's Engineering Department, working together with the renowned industrial designing firm of Peter Muller-Munk Associates, created a new fixture family that is truly outstanding.

This is the CLASSIC Series by Sylvania.

The CLASSIC achieves, through its pointed elliptical shape, the elegance and style demanded by today's leading design concepts. This new fixture group features sleek, trim lines; flared, softly-diffusing side panels; and slim shallowness . . . all of which combine to provide a graceful appearance for any interior. To satisfy individual choice, plastic louvers or plastic panels are available.

And the practical aspect has not been ignored either. In addition to its extreme attractiveness, the CLASSIC also provides other important features . . . high-quality lighting characteristics and excellent installation and maintenance advantages.

But a mere description of the CLASSIC is hardly adequate. To appreciate the true beauty and application possibilities of this series you should see the fixture itself.

Write for full information today . . . and ask to have the CLASSIC* demonstrated in your own office.

Sylvania Lighting Products
A Division of SYLVANIA ELECTRIC PRODUCTS INC.
One 48th Street, Wheeling, West Virginia

*Patent Pending

SO MODERN WITH LIGHTING BY

SYLVANIA GENERAL SYSTEM

Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

FLUORESCENT LIGHTING FIXTURES AND SYSTEMS • BEST FIXTURE VALUE IN EVERY PRICE RANGE

RETAIL STORE

Every Installation Proves the Lighting Quality of

HOLOPHANE REALITE®

OFFICE

DRAFTING ROOM

KINDERGARTEN

Featuring PRISMALUME®
(crystal acrylic plastic)

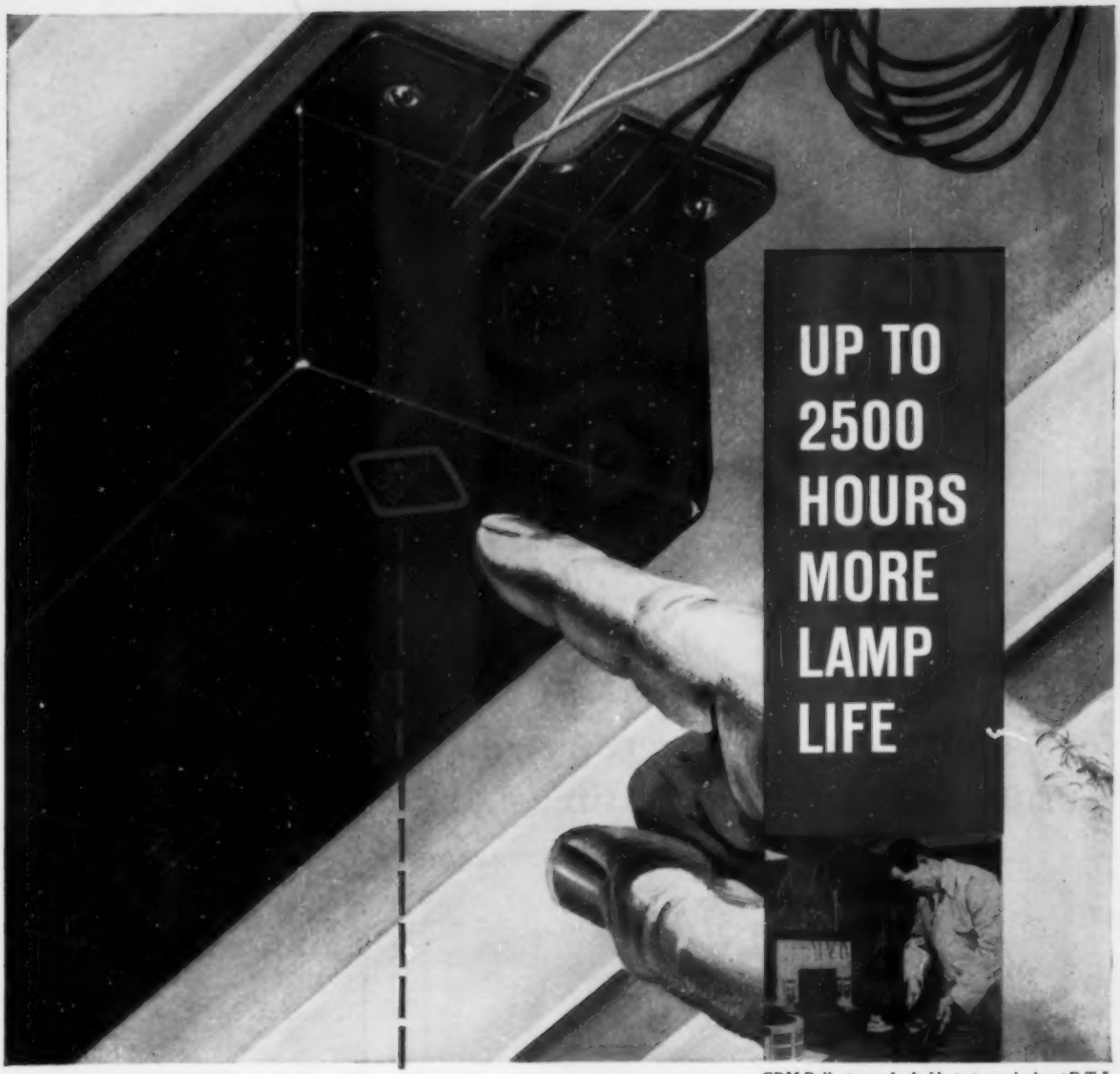
Maximum Light Control...
High Output...Low Brightness

Those who know lighting quality, have been unanimous in their acclaim of REALITE... Wherever it has been used—offices, stores, drafting rooms, schools, banks, showrooms—it has provided consistently effective results: high level illumination with the utmost visual comfort...The PRISMALUME enclosure is light in weight, shatter resistant, free from discoloration. Its prismatic control directs maximum lighting to the area where it is most needed...In terms of "life cost" per installation, REALITE® assures considerable economies.

Our engineering staff invites inquiry regarding your lighting projects...

Holophane

HOLOPHANE COMPANY, INC.
Lighting Authorities Since 1898
342 Madison Ave., New York 17, N.Y.
THE HOLOPHANE CO., LTD., 416 RIPLING AVE. SO., TORONTO 10, ONT.



CBM Ballasts are checked by tests regularly, at E.T.L.

And this is one of many advantages which this emblem on a fixture BALLAST assures you!

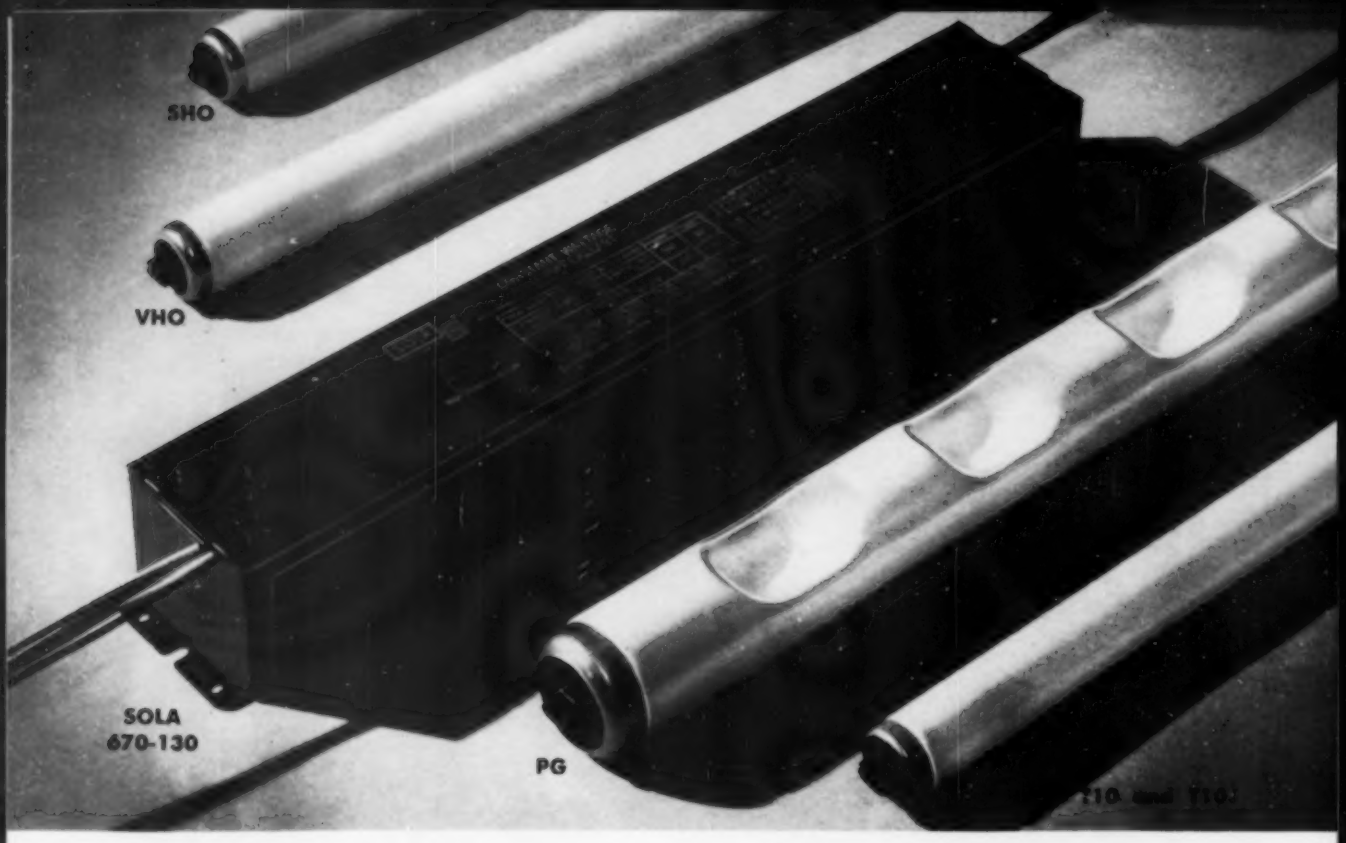
CBM CERTIFIED by ETL®

Because this CBM emblem on a ballast case means checked and certified by Electrical Testing Laboratories to definite CBM specifications . . . "Specs" that assure high light output, positive starting, Power Factor correction . . . dependable, rated performance from fluorescent lamps. And of course, UL listing. They bring other benefits, too . . . savings on installation (fewer circuits needed for fixtures CBM-equipped) and more light (from the same number of fixtures).

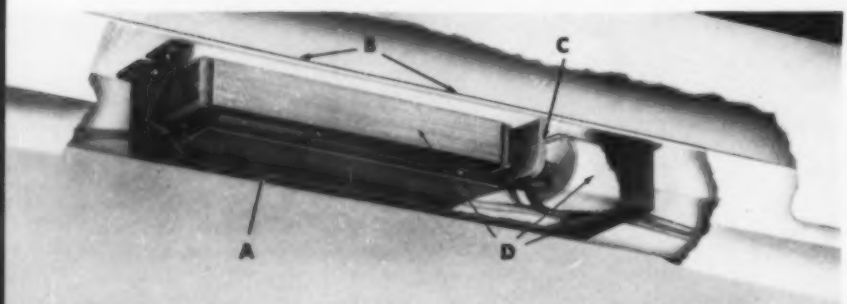
It pays to specify fixtures equipped with CBM ballasts. For the latest facts, ask us to send you CBM News.

Participation in CBM is open to any manufacturer who wishes to qualify.

CERTIFIED BALLAST MANUFACTURERS, 2112 KEITH BUILDING, CLEVELAND 15, OHIO 2-60



New, cool Sola ballast for two 1500ma lamps gives full light output, features upside-down case



Design features of upside-down ballast assure lowest in-fixture operating temperatures: **A** Fiber insulator now at label surface. **B** No thermal barrier at mounting surface to trap normal ballast heat, fixture is improved cooling fin. **C** Maximum space between capacitor and core structure gives full capacitor life. **D** Ballast temperatures substantially lower than competitive ballasts (see table at right).

Comparative Test Results

Ballast	Temperatures ° C		
	Case	Capacitor	Copper
Sola 670-130	80	60	87
Ballast X	81	70	92
Ballast Y	86	60	97

Ballasts tested in industrial fixture suspended one foot beneath ceiling while operating two, 8-foot 1500ma lamps. Ambient room temperature 25° C.

Newest member of Sola's growing family of upside-down fluorescent ballasts is Catalog No. 670-130. It operates two 96-inch 1500ma lamps down to 0° F, or two 72-inch 1500ma lamps down to -20° F.

The new ballast delivers full light output and is the coolest-operating, 18-inch, single-case unit of its type that we've tested. Results of in-fixture comparative tests of the Sola ballast and its two competitors are shown above. Further tests prove that Catalog No. 670-130 easily meets proposed CBM specifications for two-lamp 1500ma ballasts.

A good share of the new unit's improved performance and life-extending operating temperatures is a result of Sola's ingenious solution to the problem of heat dissipation which is diagramed above.

The next time you need a ballast that will help quality fluorescent fixtures deliver all the light that's engineered into 1500ma lamps, that will give coolest possible in-fixture performance, that will live up to its own rated life, that's the time to specify Sola Catalog No. 670-130. Engineers and fixture manufacturers are invited to send for sample ballasts.

Write for Bulletin 3B-FL

SOLA

A DIVISION OF BASIC PRODUCTS CORPORATION

Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill.

What more important single factor is there in an Art Museum, besides the paintings themselves, than the light to see them by?

EXTRU-LITE† SPECIFIED BY

AMERICAN LIGHTING CORP. FOR

SOLOMON R. GUGGENHEIM MUSEUM

DESIGNED BY

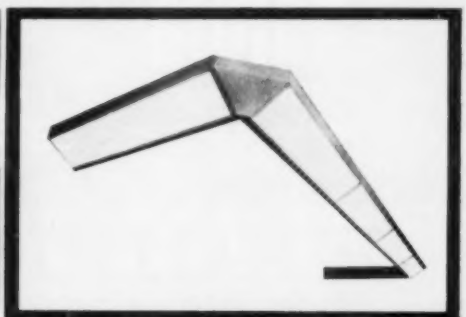
FRANK LLOYD WRIGHT

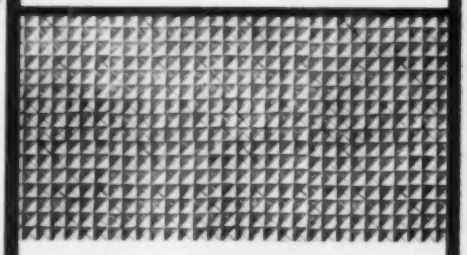
Frank Lloyd Wright designed the architecture to capture the daylight. Within the building, the fluorescent lighting cleverly blends with the natural light. Result: High level, glareless illumination . . . ideal for viewing art.

James Johnson Sweeney, Director of the Museum, Alfred Binder, Illuminating Engineer and Designer for American Lighting Corp., and A. E. Alper, Installation-Engineer of Daylight Elec. Construction Corp., are the men responsible for this tremendously effective lighting application. Much credit is due them for their new concepts of creation, courageous experimentation and zeal for perfection. That EXTRU-LITE was chosen is a tribute to its shielding excellence.

On the interior frontal ramp, 3-lamp fluorescent Luminaires are hung flush to the ceiling with the light source placed at an angle of abt. 40 degrees. The Luminaires form a U (see illus.) conforming to the gallery shape.

Each Luminaire uses 3 lamps. The ratio of illumination is approx. 2 to 1 in lumens — Cool White to Warm White. Crystal-clear EXTRU-LITE, (Rotuba's extruded plastic shield having over 9,000 prisms per sq. ft. and here made with Plexiglas®†) combines the 2 colors to achieve a diffuse, warm-enlivened light. Further, it gives brightness control with the desired illumination level in the viewing area.





Prismatic Extru-Lite is all plastic, either Polystyrene or Acrylic. It is tough, lightweight (approximately .6 lbs. per sq. ft. in ⅛" thickness), easy to clean, and safe to handle.

Besides this highly publicized, highly specialized Museum job, Extru-Lite has been used successfully for over 5 years in thousands of installations, such as schools, banks, office buildings, hospitals and churches.

That's why we say, for the Best Buy in Sight
— Specify Fixtures using EXTRU-LITE.

Send for our Fact Sheet and Samples today

ADDITIONAL OFFICES: O'Connell & Associates, Chicago, Ill., AMbassador 2-3841 — Robert L. Bouse Co., Flourtown, Pa. (Phila.) Chestnut Hill 8-1010

THE ROTUBA EXTRUDERS, INC.

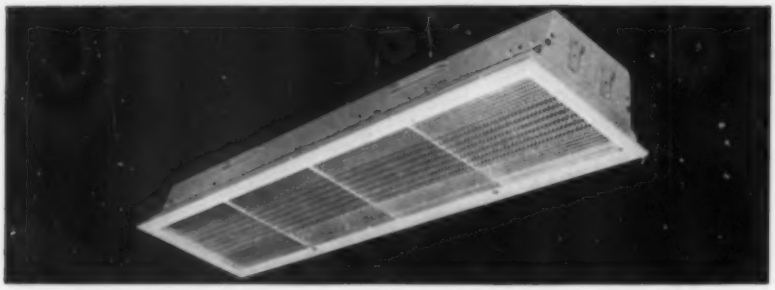
A DIVISION OF WALJOHN PLASTICS, Inc.

MAKERS OF PLASTIC EXTRUSIONS FOR INDUSTRY

437 88th STREET, BROOKLYN 9, NEW YORK • SHORE ROAD 8-5458

†Rohm-Haas
® Reg. T.M.

EXCLUSIVE

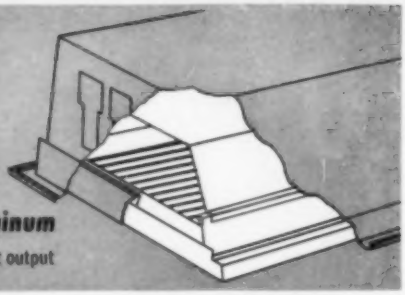


only **aurora**

RECESSED TROFFERS

give you this built-in "light trap" of extruded aluminum

Seals troffer interior, increases useable light output



EXCLUSIVE

only **aurora**

gives you this extruded aluminum slide-in frame for glass and plastic diffusers

Tapered for hairline fit, lightproof closure

EXCLUSIVE

only **aurora** ***gives you this total combination for better troffer lighting***

- ★ All exposed surfaces of aluminum
- ★ Adapts to any ceiling
- ★ All sizes to 4 x 4, including new 18″-wide series
- ★ Choice of 19 shieldings including Holophane lenses*
- ★ Modular dimensions . . . fast, easy installation
- ★ Flexible lamp arrangements
- ★ Circu-vent design for heat dissipation

Get the complete AURORA story . . . write today for our new Bulletin T-759.

*authorized Holophane distributor

metco Lighting

SOLD ONLY THROUGH QUALIFIED ELECTRICAL DISTRIBUTORS

METALCRAFT PRODUCTS CO., INC., 6225 State Road, Phila. 35, Pa.

(Continued from page 18A)

and Virginia, with headquarters in Norristown, Pa. He succeeds **Richard Dulude,** who becomes a product specialist for the company's Lighting Sales Department at Corning, N. Y.

The Optical Society of America has established a new membership classification, designated as Fellow, for those members who have "served with distinction in the advancement of optics." Ten staff members of the National Bureau of Standards have been honored with Fellowship status: **Dr. Irvine C. Gardner, Dr. Kasson S. Gibson, Dr. Deanne B. Judd, Harry J. Keegan, Dr. Carl C. Kies, Dr. Fred L. Mohler, Dr. Earle K. Plyler, Bourdon F. Scribner, Dr. Charlotte M. Sitterly** and **Ray P. Teele.** Messrs. Gibson, Judd and Teele are also IES members (Gibson and Teele, IES Fellows).

Laurance C. Messick, manager of the National Lighting Bureau, has been appointed director of the Medallion Home Program, according to an announcement by Joseph F. Miller, managing director of the National Electrical Manufacturers Association. NEMA assumed national responsibility for the administration of the program this year.

Alva A. Togesen has joined the Curtis Lighting Division, Curtis-AllBrite Lighting, Inc., Chicago, Ill., as manufacturer's representative for the Detroit territory. Prior to forming his own agency, Mr. Togesen was vice president—marketing for the BullDog Electric Products Co., Detroit, Mich.

Crouse-Hinds Co., Syracuse, N. Y., has announced the transfer of **Walter A. Short,** a product engineer, to Buffalo. He was formerly a product engineer in the Boston region. Other personnel changes announced include the move of **Chester C. Pratt,** former Buffalo product engineer, to Detroit to become regional manager for that area. **William J. Feahr** has been named divisional manager of the Great Lakes Division of the company's Cleveland office. His division takes in the territory served by the Cleveland and Detroit regions.

Plans for an addition to the Chicago plant of the Advance Transformer Co. have been announced by **Louis Duman,** president of the company. This addition, the second in a year, will house the company's Star Metal Products Division.

Pergamon Press Inc. has established a branch in Washington, D. C., according to an announcement by **Capt. I. R. Maxwell,** president of the publishing house. The new office, under the direction of

(Continued on page 34A)

"Equal to RLM" ...Anyone can Say it!

BUT

Only the RLM LABEL can GUARANTEE IT with a continuous RLM Test Program of Inspections by the ELECTRICAL TESTING LABORATORIES

"Equal to RLM" is a claim that is often made by sellers of industrial lighting equipment. No finer compliment could be made to the high quality RLM specifications!

However, RLM is more than a group of widely approved standards for industrial lighting equipment. RLM is also a guarantee of conformance. This guarantee is backed by the unbiased tests conducted by an independent testing laboratory—The ELECTRICAL TESTING LABORATORIES OF NEW YORK! These tests assure not only compliance with standards but every effort is made to insure that *every fixture* shipped to the buyer will be of uniform quality.

In the entire lighting industry there is no equal to this testing program... so in the truest sense there can be no such thing as "equal to RLM." RLM is unique... distinctive and above price to the buyer who wishes unbiased proof of quality.

THE FINAL INGREDIENT OF BEING SURE

Into each factory go ETL representatives to secure for test and certification purposes, samples of the manufacturer's RLM-labeled units.

PRODUCT QUALITY
LIGHTING QUALITY

These TWIN QQ's to Industrial Lighting Success
are guaranteed with all lighting equipment bearing the RLM Label.
Return of the coupon brings you full information.

RLM STANDARDS INSTITUTE, Suite 8232, 326 W. Madison, Chicago 6, Ill.

Please send me free a copy of the new "TWIN QQ's" pamphlet, the latest RLM SPECIFICATIONS BOOK, and names of the leading manufacturers offering RLM-labeled lighting equipment. (Please write name, company and address in margin below.)

R-763

Photo courtesy of Western Electric Co.
Architects & Engineers: Lockwood Greene

This is *PRACTICAL* MAINTENANCE . . . WITH *Servisafe* POLES

In less than 10 minutes, this man will have finished replacing a burn-out and cleaning a luminaire. It's a fast, efficient, no sweat job. He is free from climbing hazards, and the lowered fixture is dead. In addition, his only "auxiliary" equipment is a detachable handline!

The unique advantages of Thompson "Servisafe" Metal Poles assure year-round all-weather lighting maintenance at minimum cost. In fact, there is no easier, safer or more economical method of servicing pole-mounted luminaires.

FOR DETAILS AND PRICES, WRITE FOR BULLETIN PWB-59.

8814-TE

T-E

THE THOMPSON ELECTRIC CO.

P. O. BOX 873-K CLEVELAND 22, OHIO

(Continued from page 32A)

Detlev J. Raymond, will be available to undertake the editing, publishing and printing of scientific books, magazines and symposia.

Three new appointments to the sales force of Lightolier Inc., Jersey City, N. J., have been recently announced. **Gerald Portnoy** has been assigned all accounts in southeast Maryland and the York-Lancaster area of Pennsylvania, as well as all lamp accounts in Washington. **Richard Brayer** will cover most accounts in Indiana and **Daniel Spindler** will concentrate on commercial accounts in the greater Los Angeles area.

Deaths

Henry S. Kelly, Connecticut Section
Walker Field, New York Section
Lester B. Free, New York Section

BOOKS AND PAMPHLETS

A Bright City is a Safe City, available from Lighting Standard Division, Kerrigan Iron Works Co., Nashville, Tenn. No charge.

Basic street lighting principles, including IES recommended light distribution patterns, tables of mounting heights and recommended footcandle levels for various traffic volume conditions are outlined in this 20-page booklet, designed to aid in the planning and promotion of better street lighting. Illustrated case histories of relighting programs in several cities emphasize the many benefits to be derived from a good street lighting program.

Wiring Devices, WD 2-1959, available from National Electrical Manufacturers Association, 155 East 44th St., New York 17, N. Y. 20 cents.

Material covered in this publication includes the essential dimensions of the lamp shoulder gauge for medium base lamps and the colors of molded compounds for wiring devices.

American Standard Requirements for Electrical Indicating Instruments (Panel, Switchboard and Portable Instruments), **EI 1-1959,** available from National Electrical Manufacturers Association, 155 East 44th St., New York 17, N. Y. $2.50.

This American Standard, also a NEMA Standard, applies to the following kinds of electrical indicating instruments:

(Continued on page 36A)

LIGHTING FOR A FRIENDLY ATMOSPHERE

Patents Pending

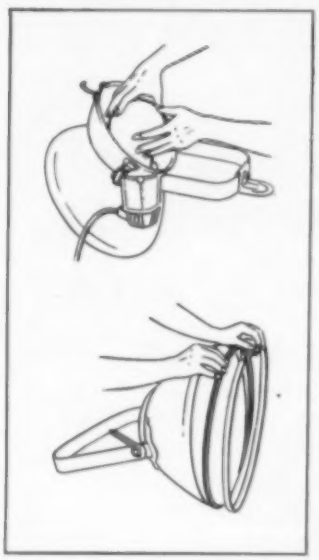
There is more to lighting than footcandles. The creation of an aesthetic environment and a friendly atmosphere are equally essential to most if not all human tasks. To this end Sunbeam Lighting Company dedicates a new and beautiful Sculpturama® series (QRH7502). The all-curved styling of this 2-lamp unit is combined with the inwardly curved Holophane Prismalume* acrylic lens panel. This blend of gentle curves results in excellent low brightness control both from the illuminated metal sides and the prismatically sharp Prismalume*. No visible "hardware" mars the clean, sculptured look of this unit. Now, you can have lighting fixtures which will supply both footcandles and friendly styling to your interiors. An added bonus comes your way in the form of comfortable, low brightness illumination.

SUNBEAM LIGHTING COMPANY
777 East 14th Place, Los Angeles 21, California
3840 Georgia Street, Gary, Indiana

For more details ask for bulletin A84G.

* ® Holophane Co., Inc.

New Steber Series 5000—Rear Lamped Floodlights—are designed to meet NEMA Specifications FL6-210, Group B, Types I, II, III, IV and V. They accommodate G-48, 1500 watt, PS-52, 750-1000-1500 watt incandescent and 400-700 watt Mercury Vapor lamps.



In addition to "rear-lamping," Series 5000 floodlights include these exclusive Steber features:

1. Genuine Silicone gasketing at all critical points
2. Finned, cast aluminum neck and cap for maximum heat dissipation
3. Shielded condensate drain
4. Removable thermal shock and impact-resistant lens
5. Rear section clips to trunion bracket, leaving both hands free for faster, safer servicing
6. Positive grounding—both during operation and servicing

DELIVERIES

The well-known Steber "shipment within 16 working hours" policy applies to Series 5000 Floodlights, as well as to all other Steber lighting equipment. No need to wait 6 to 8 weeks or longer for "rush" jobs—specify Steber and your delivery problem is solved.

Write for NEW BULLETIN 1097 today!

Lighting Units **STEBER** *for Every Need*

STEBER MANUFACTURING CO., DEPT. 66-B, BROADVIEW, ILL.

Steber Manufacturing Co. of California, 242 S. Anderson St., Los Angeles 33, Cal.

Divisions of The Pyle-National Company

(Continued from page 34A)

ammeters, voltmeters, wattmeters, varmeters, frequency meters, power-factor meters and indicating instruments functioning on the above principles but indicating derived quantities. The Standard is also applicable to those instruments with prefixes such as micro- and kilo-.

NEW MEMBERS

At the meeting of the IES Council Executive Committee on January 5, 1960, the following were elected to membership. Names marked * are transfers from Associate Member Grade. Names marked ** are transfers from Student Member Grade.

ALABAMA SECTION

Associate Member:

Potter, R. A., Gulf Power Co., Pensacola, Fla.

ARKANSAS SECTION

Members:

*Barry, E. G., Arkansas Power & Light Co., Little Rock, Ark.

*Williams, J. S. IV, Arkansas Power & Light Co., Little Rock, Ark.

ARROWHEAD CHAPTER

Associate Member:

Robertson, W. D., California Electric Power Co., Palm Springs, Calif.

BLUENOSE CHAPTER

Member:

Matheson, D. T., Bryant Electric Co., Ltd., Halifax, N. S.

BUCKEYE CHAPTER

Members:

Hines, P. T., General Electric Co., Circleville, Ohio.

*Mast, L. R., H. A. Williams & Associates, Columbus, Ohio.

Metzger, W. E., Walter E. Metzger & Associates, Columbus, Ohio.

*Murnane, T. A., General Electric Supply Co., Columbus, Ohio.

*Odle, H. A., Holophane Co., Inc., Newark, Ohio.

*Risler, H. E., Westinghouse Electric Supply Co., Columbus, Ohio.

Associate Members:

Gilliland, V. L., Ohio Power Co., Newark, Ohio.

Ridge, W. F., Ohio Midland Light & Power Co., Canal Winchester, Ohio.

**Schwab, R. N., Institute for Research in Vision, Ohio State University, Columbus, Ohio.

Whipps, H. M., Drake & Ford, Columbus, Ohio.

Student Member:

Newsome, R. K., Robert S. Curl & Associates, Columbus, Ohio.

CENTRAL KANSAS CHAPTER

Associate Member:

Mohler, R. H., American Electric Co., Wichita, Kans.

CENTRAL NEW YORK SECTION

Members:

*Estabrook, D. E., New York State Electric & Gas Corp., Oneonta, N. Y.

*Meade, R. E., New York State Electric & Gas Corp., Oneonta, N. Y.

Associate Members:

Johnson, J. A., Sylvania Electric Products Inc., East Syracuse, N. Y.

(Continued on page 39A)

ABOVE ALL:

LUSTREX PERMA TONE STYRENE LIGHTING ENCLOSURES

Lighting enclosures in Lockheed Aircraft Corp. Building, Sunnyvale, Calif. by Day-Brite Lighting, Inc., St. Louis, Mo.

Electrical Engineers: Keller and Gannon of San Francisco, Calif.; Contractor: Central Electric Co.

WHY? 2 to 3 times more resistance to yellowing than general purpose styrene! (Perma tone—specially developed to meet IES-NEMA-SPI joint specifications for ultra violet light-stabilized styrene—exceeds the requirements of these specifications).

WHY? Unlimited translucencies in white and complete color range.

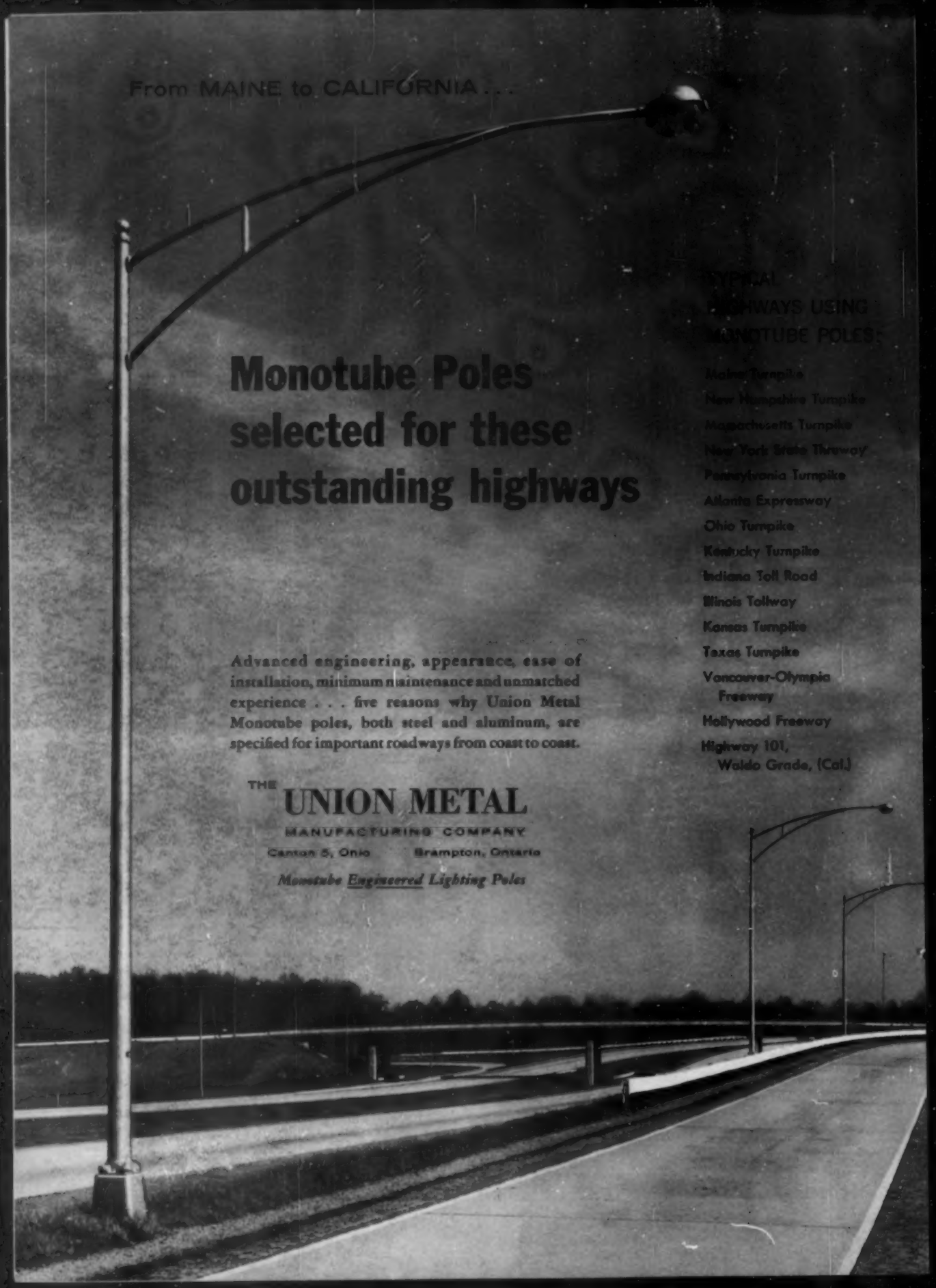
WHY? All the general advantages of styrene in lighting: large area of illumination, good diffusion; light weight for easy handling, installation, and maintenance; good dimensional stability; low cost.

WHY? Proven in use by leading fixture manufacturers, molders, lighting engineers, architects. No formulation modifications since 1956.

For free Technical Report on Lustrex perma tone styrene, including accelerated test results and other valuable data on styrene in lighting, write to Monsanto Chemical Co., Plastics Division, Room 661 Springfield 2, Mass.

LUSTREX: Reg. U.S. Pat. Off.

Monsanto


From MAINE to CALIFORNIA . . .
Monotube Poles selected for these outstanding highways
TYPICAL HIGHWAYS USING MONOTUBE POLES:
Maine Turnpike
New Hampshire Turnpike
Massachusetts Turnpike
New York State Thruway
Pennsylvania Turnpike
Atlanta Expressway
Ohio Turnpike
Kentucky Turnpike
Indiana Toll Road
Illinois Tollway
Kansas Turnpike
Texas Turnpike
Vancouver-Olympic Freeway
Hollywood Freeway
Highway 101, Waldo Grade, (Cal.)
Advanced engineering, appearance, ease of installation, minimum maintenance and unmatched experience . . . five reasons why Union Metal Monotube poles, both steel and aluminum, are specified for important roadways from coast to coast.
THE UNION METAL MANUFACTURING COMPANY
Canton 5, Ohio Brampton, Ontario
Monotube Engineered Lighting Poles

(*Continued from page* 36A)

Orshaw, G. W., Brady Supply Corp., Elmira, N. Y.
Smith, M. R., New York State Electric & Gas Corp., Binghamton, N. Y.

CENTRAL OKLAHOMA CHAPTER

Associate Member:
Perkins, L. B. Jr., Perkins Brothers Sales Co., Oklahoma City, Okla.

CHICAGO SECTION

Members:
*Foulkes, J. F., United Air Lines, Chicago 38, Ill.
*Starr, S. M., Revere Electric Mfg. Co., Chicago, Ill.

CLEVELAND SECTION

Member:
Budish, I. I., Dalton-Dalton Associates, Cleveland, Ohio.

CONNECTICUT SECTION

Associate Member:
Kaye, Malcolm, Wheeler-Fullerton Lighting Division, Franklin Research Corp., Norwalk, Conn.

CORNHUSKER SECTION

Associate Member:
Williamson, R. D., Owens-Corning Fiberglas, Omaha, Nebr.

DIABOLO SECTION

Member:
*Scarff, D. D., General Electric Co., Oakland, Calif.

Associate Member:
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(*Continued on page* 41A)

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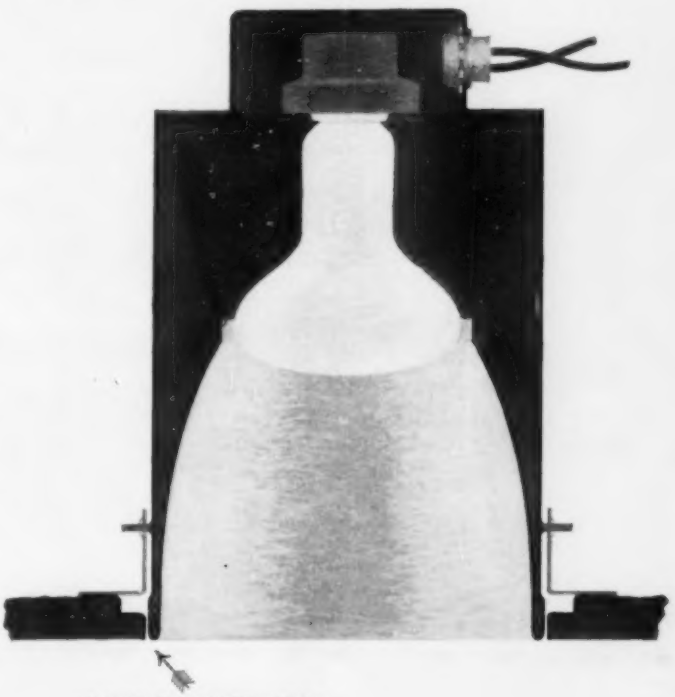

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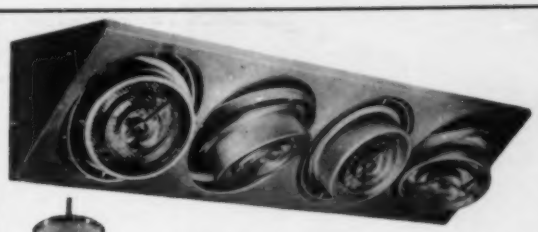

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(Continued on page 42A)

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the high ceiling
GLARE-FREE
recessed downlights

For AUDITORIUMS, LOBBIES, BANKS, SCHOOLS, HOSPITALS, THEATRES, ARENAS, AIRPORT or RAILROAD TERMINAL BUILDINGS and other high ceiling applications where comfortable light with glareless source is required.

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33a
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(*Continued from page* 41A)

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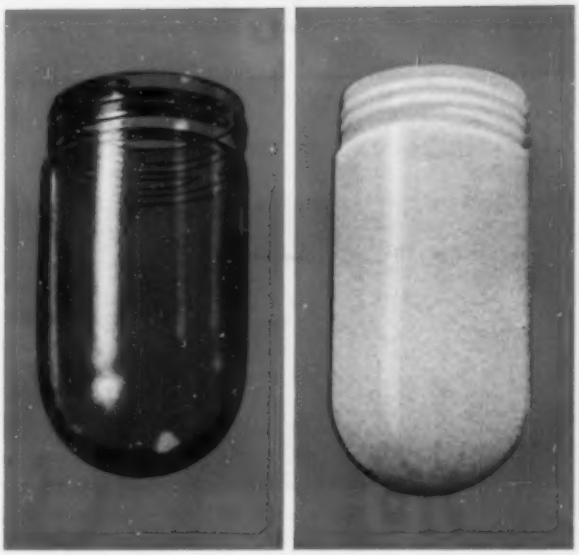
globes



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Revere ELECTRIC MFG. CO.

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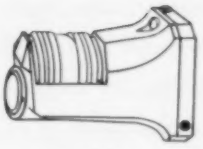
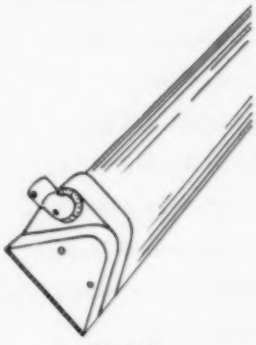


No. 3151-A
Underneath Floodlight

Lighting an automobile dealership

The Problem: To highlight the front of an automobile showroom exterior, showing to best advantage the face of the building and its distinctive identification.

The Solution: A continuous line of Revere Fluoresign luminaires were installed at cornice height, running the entire length of the surface to be lighted. The integral luminaires have an adjustable feature which permits accurate placement of light for smooth, even lighting. Enough spill light occurs on sidewalk for inviting atmosphere.



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The Problem: To put an extremely high level of light on a service station's pump islands and service areas. Station must be unusually attractive to meet competition.

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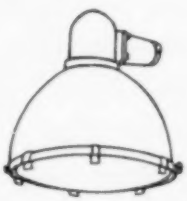

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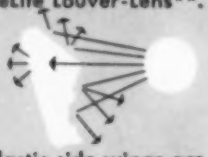

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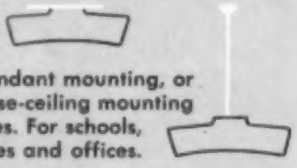

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